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ABSTRACT

This manual provides information needed to meet the standards for pesticide applicator certification. Section one is concerned with the morphology, life cycle and breeding areas of mosquitoes and the diseases resulting from their presence. The second section covers similar categories in relation to the black fly population. Calculation methods and conversions for pesticide application are discussed and illustrated in part three. Application equipment, techniques and effectiveness are presented in the last section. (CS)

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COOPERATIVE EXTENSION SERVICE

University of New Hampshire

MOSQUITO AND BLACKFLY

CATEGORY MANUAL

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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COMMERCIAL PESTICIDE APPLICATOR TRAINING

This training manual is intended to provide you with the information you will need to meet the standards of the Environmental Protection Agency for pesticide applicator certification, and prepare you to take an examination given by the State Department of Agriculture based on this manual. It is not intended to provide you with all the information you need for effective mosquito and black fly control. Additional information in the form of publications and short courses can be obtained from the Cooperative Extension Service.

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Section 1: Mosquitoes

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1. MOSQUITOES

Mosquitoes are considered one of mans greatest enemies. The discovery, in 1898 by Ronald Ross, that mosquitoes transmit malaria, awakened man to their extreme importance. They transmit several serious and distressing diseases such as malaria, yellow fever, dengue, filariasis, and a number of viral encephalitides. Animal diseases transmitted by mosquitoes include such things as dog heartworm, bird malaria, fowl pox, and several encephalitides which may affect horses. More detailed information will be given later in this manual.

The toll of the mosquito may be regarded from three aspects:

1. Annoyance, suffering and death caused by bites and diseases it transmits.
2. The economic loss resulting from these diseases in expenditures for medical aid, nursing, medicines, control and in loss of time and production.
3. Economic loss by holding back development of, and depressing property values in sections where they are plentiful.

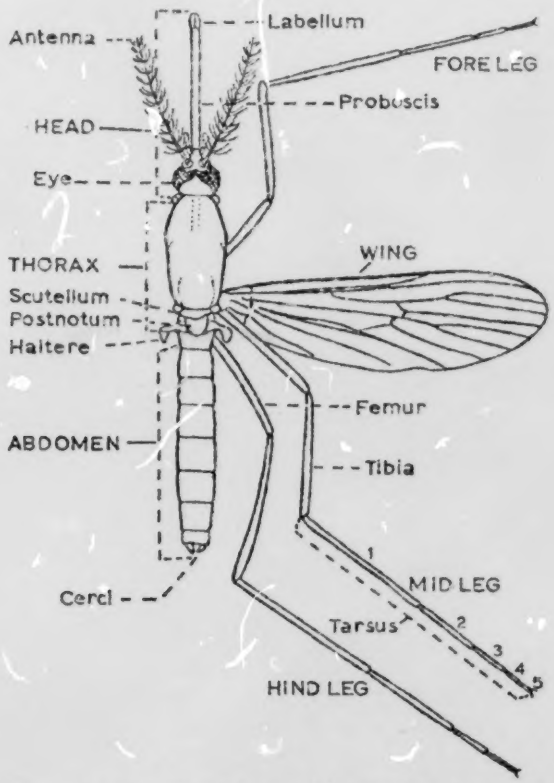
A. Mosquito Morphology

Mosquitoes are small, 2-winged insects in the family Culicidae of the order Diptera. They can be distinguished from most other flies by:

1. A long proboscis projecting forward from the head.
2. Presence of scales on the wing veins.
3. A fringe of scales along the posterior margin of the wing.
4. Characteristic wing venation - the second, fourth, and fifth longitudinal veins being branched.

1. Adult

The adult has three distinct body regions: head, thorax, and abdomen.



An adult (female) mosquito (after Marshall, 1938)

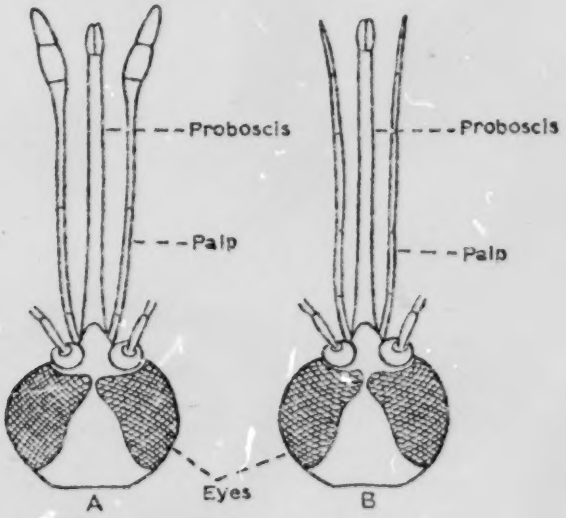
a. Head: The head bears two large compound eyes (ocelli or simple eyes are lacking), long antennae and the proboscis.

Antennae are segmented and at each joint there can be found a whorl of hairs. The male has dense long bushy hairs while the female has short, sparse hairs.



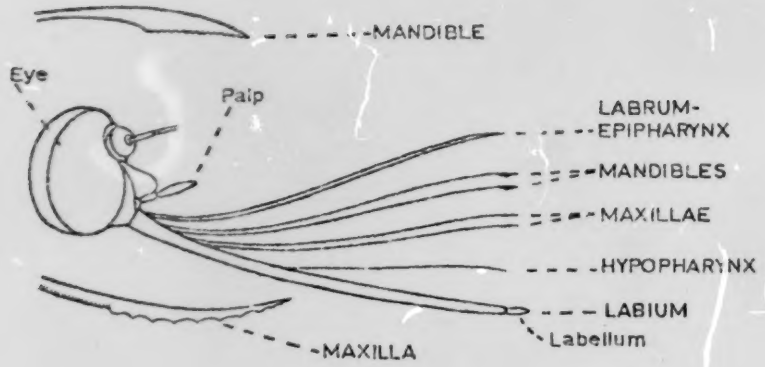
Antenn[illegible] of (a) a female and (b) a male mosquito (after Marshall, 1938)

The maxillary palps also differ in the male and female.

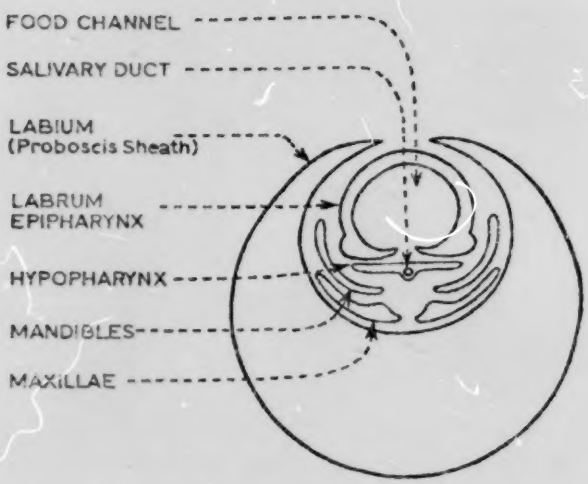


Head and mouthparts of (a) a male and (b) a female anopheline mosquito

The proboscis is an intricate apparatus used by the females of most mosquito species for piercing and sucking. It consists of 6 elongated parts enclosed in a flexible sheath called the labium, a hollow, cylindrical tube, narrowly open along its dorsal surface and terminating in a pair of small lobes called the labellae.

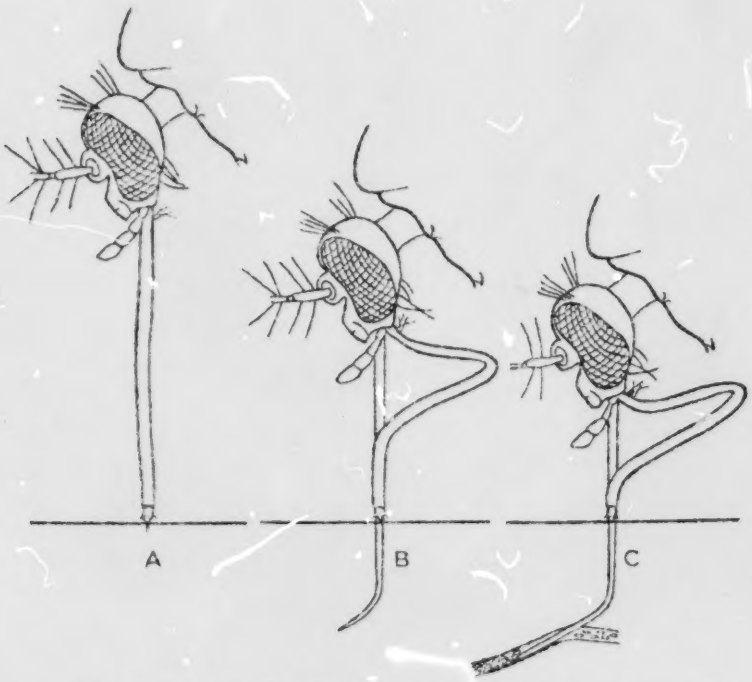


Side view of the mouthparts of a female mosquito (modified from Marshall, 1938)



Cross-section of the proboscis of a female mosquito
(diagrammatic. After Marshall, 1938)

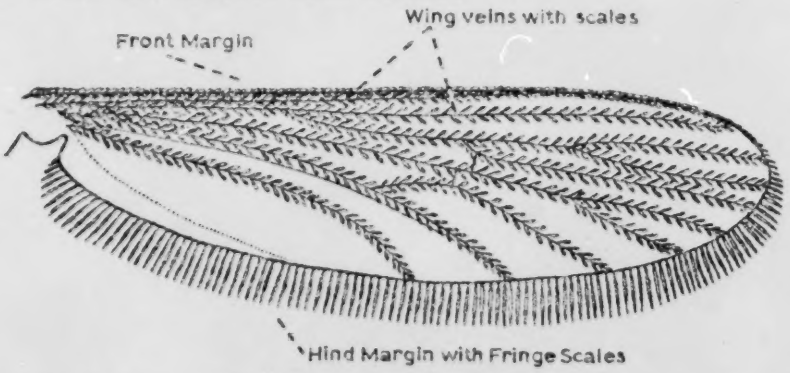
During the act of biting, the labium never enters the wound. It is used as a protective sheath and guides the stylets.



Successive stages in the penetration of the stylets of a female mosquito feeding on blood ((a) modified from Snodgrass, 1959; (b and c) modified from Gordon and Lumsden, 1939)

b. Thorax: The thorax is wedge-shaped, being broader above than below, and bears 3 pairs of legs, one pair of wings, and halteres. The thorax is divided into 3 distinct regions - the prothorax, the mesothorax, and the metathorax. The wings are found on the mesothorax and the halteres on the metathorax. Each segment bears a pair of legs.

Wings are elongate to oval in shape and their venation is uniform throughout the family. The veins are covered with scales.



Wing of a mosquito, showing scales on the wing veins and along the posterior margin (diagrammatic)

c. Abdomen. The abdomen is composed of ten segments, the last two being modified for opipositon (female) and copulation (male).

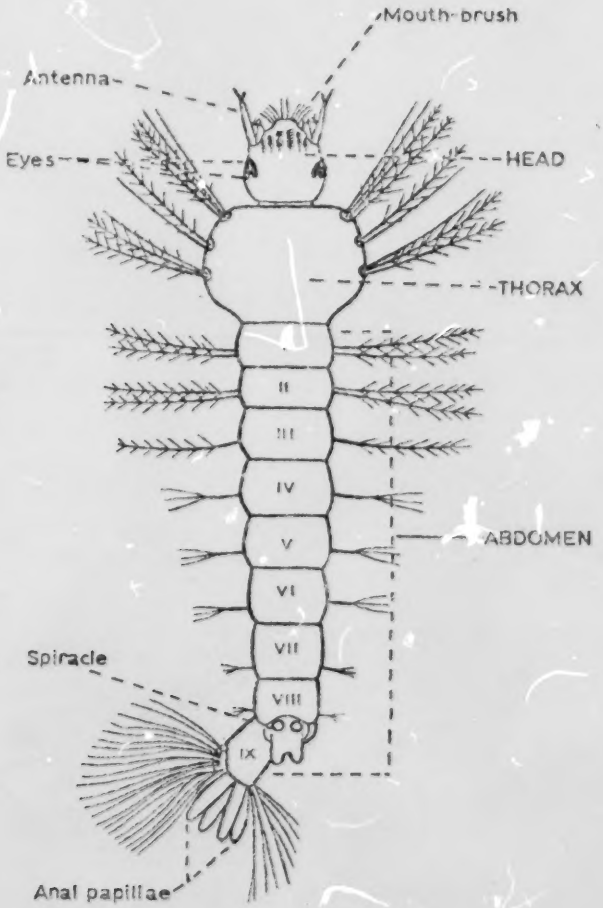
2. Larva

The larva has 3 distinct body regions: head, thorax, abdomen.

a. Head: The head bears the two compound eyes, small accessory eyes which are immediately behind them, antennae, and mouthparts which consist of the labrum, mouth-brushes, mandibles, maxillae (with palps) and labium.

b. Thorax: The thorax consists of three fused segments. They are not clearly differentiated and can be distinguished only by groups of hairs called setae which are found on each thorasic segment. Legs are absent.

c. Abdomen: The abdomen is comprised of 9 segments. The eighth segment bears the breathing tube. This may vary in form with the different genera. In all mosquitoes, the ninth segment bears dorsal and ventral brushes and four anal papillae.



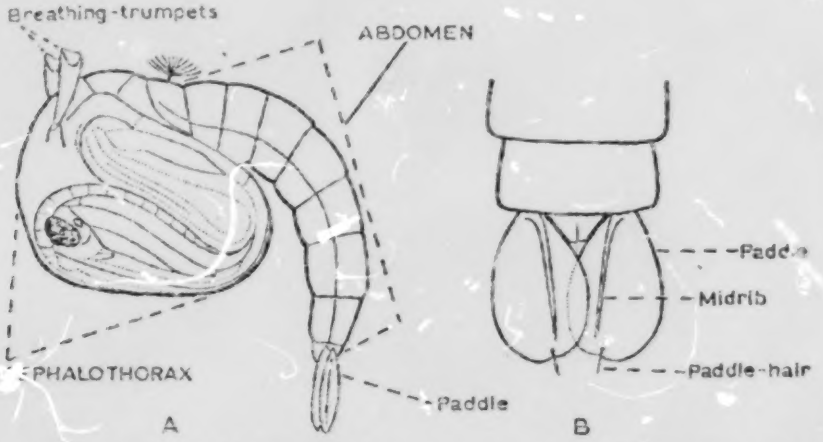
Anopheline larva

3. Pupa

The pupa is "comma-shaped" and divided into 2 regions: cephalothorax (enlarged anterior part) and the slender abdomen.

The cephalothorax is composed of the flattened head and the thorax. From the back of the thorax can be found two "horns" known as respiratory trumpets. These are the external openings of the pupal respiratory system. These trumpets may vary with each genus.

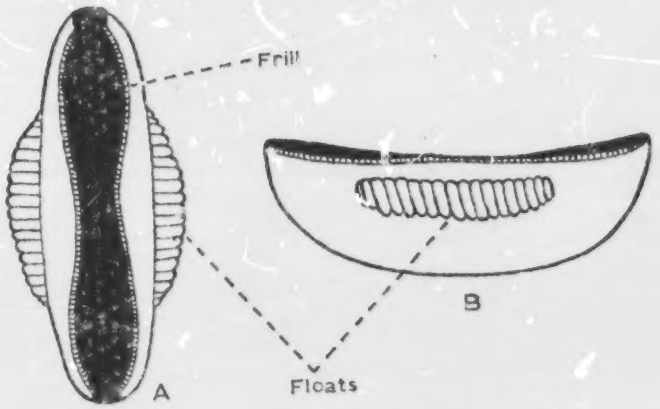
The abdomen consists of 9 somewhat flattened, freely moving segments, the terminal one being smaller than the others. At the end are a pair of large flattened plates or paddles, which enables the pupa to swim in water.



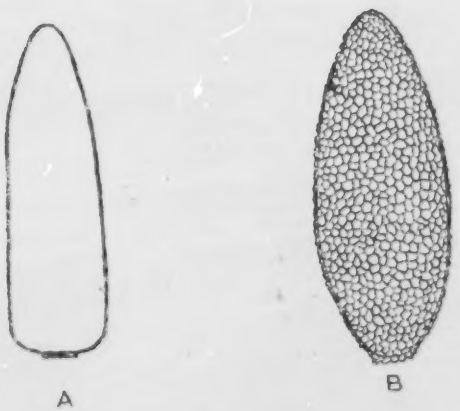
Pupa: (a) generalized, (b) terminal abdominal segments (modified from Marshall, 1938)

4. Eggs

Eggs differ considerably with each genus. Some mosquitoes deposit their eggs in masses which are known as rafts. Culex, Culiseta, and Mansonia eggs are laid in rafts on the surface of standing water. Anopheles lay eggs singly on the surface of the water. Others are known to deposit their egg singly on moist soil. Aedes and Psorophora are prime examples. The eggs of these two genera are resistant to drying and some species require that the area dry out thoroughly and reflood before hatching. Hatching takes place in several days in Anopheles and Culex to several weeks or months in Aedes and Psorophora. The latter two genera may enter into diapause if conditions are not favorable.



Egg of Anopheles: (a) dorsal view, (b) side view

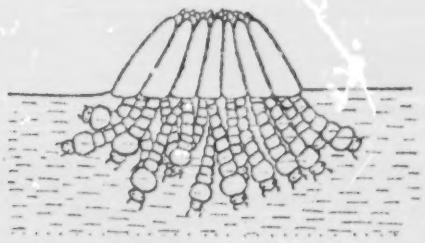


Eggs of (a) Culex and (b) Aedes ((b) after Marshall, 1938)

B. Life Cycle

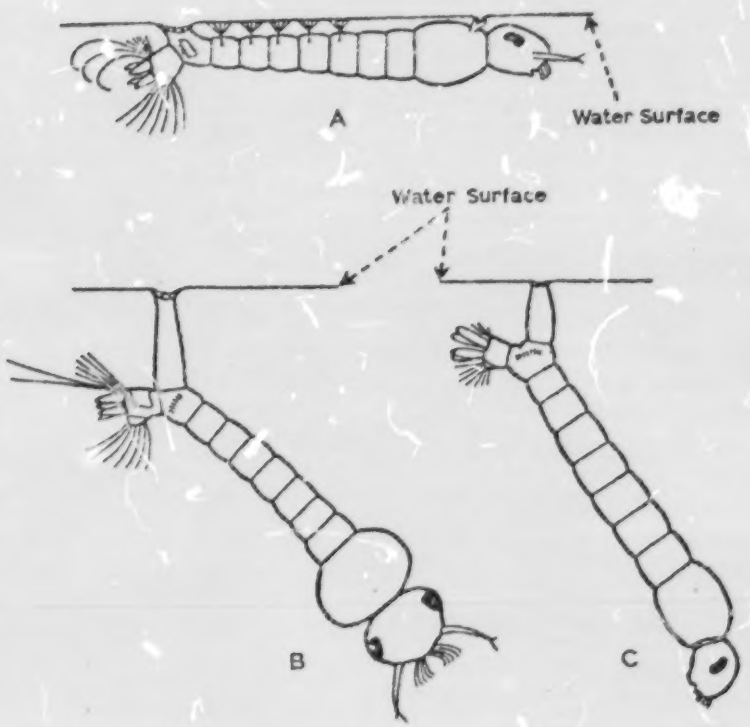
In order to become a competent mosquito control specialist, it is important to know the life cycle of mosquitoes and their variations among the problem species in your area. Mosquitoes may vary in their biology, but there are certain characteristics which are common to all species. All mosquitoes pass through complete metamorphosis: egg, larva or wiggler, pupa or tumbler, and adult. All larval and pupal forms require water to complete development.

Eggs are generally produced in three different forms: Those that are deposited singly in water, those in masses of 100 - 300 eggs which float on the surface of water, and those that are deposited singly on moist surfaces such as damp earth, along margins of pools or ponds, or just above the water line of a tree hole or artificial container. Eggs hatch in 2-3 days but if conditions are unfavorable, they may not hatch for months or even years.



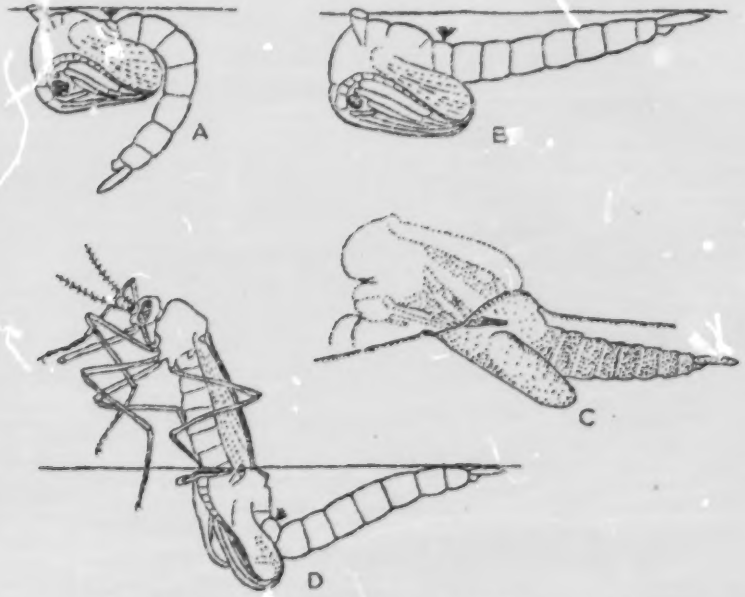
Culex larvae hatching out from an egg-raft
(adapted from a photograph in Marshall, 1938)

Larvae are also referred to as wigglers. They receive the name from their mode of locomotion. All larvae, with the exception of Mansonia, must return to the surface of the water to obtain oxygen. Mansonia has an air tube which can pierce stems and roots of aquatic plants where they obtain oxygen. The larvae go through four stages of development called instars during which time they feed on microscopic plants, animals and organic debris.



Resting positions of (a) *Anopheles*, (b) *Culex* and (c) *Aedes* larvae
(a) and (b) adapted from Marshall, 1938; (c) after Christophers, 1960)

The non-feeding pupae are formed after the 4th larval instar. This stage is also referred to as tumblers since they move in a somersaulting fashion. The pupal stage normally gives rise to an adult mosquito after 1 to 3 days depending upon weather conditions.



Successive stages in the emergence of an adult mosquito from a pupa
((c) after Christophers, 1960; (d) modified from Snodgrass, 1959)

Adult mosquitoes feed on nectar, plant juices and in the case of females, blood. Males do not feed on blood because their mouthparts are not rigid enough to penetrate through animal skin. Blood is necessary to many species to enable females to develop their eggs.

Males live about a week while most females survive 2-4 weeks.

Mosquito migration varies. The common house mosquito, Culex pipiens, has a flight range of ¼-½ mile. Aedes sollicitans, the salt marsh mosquito, has a range of up to 40 miles.

Overwintering also varies within the mosquito family.

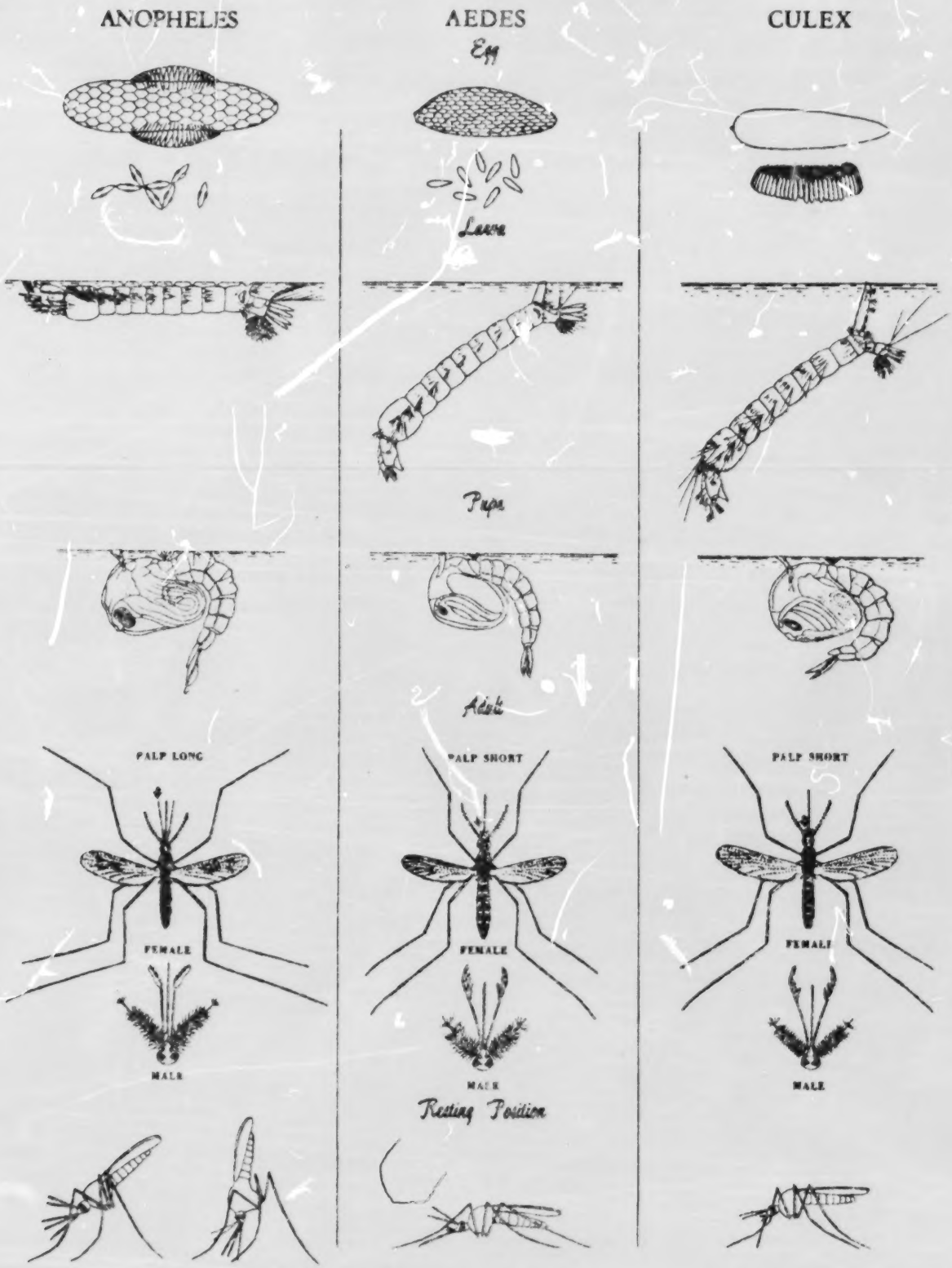
1. Aedes and Psorophora: most overwinter as an egg. Aedes hatches in early spring when flooded by melting snow and rain. Psorophora hatches after summer rains.

2. Culex, Anopheles, and Uranotaenia: overwinter as adults in sheltered areas such as buildings.

3. Mansonia perturbans: overwinters as a larva attached to roots of aquatic plants; Wyeomyia smithii overwinter as larvae in water of the pitcher plant; Culiseta melanura larva overwinters under and sometimes in ice of small bodies of water and in mud.

MOSQUITOES: CHARACTERISTICS OF ANOPHELINES AND CULICINES

Kent S. Littig and Chester J. Stojanovich



TYPES OF LIFE HISTORIES OF MOSQUITOES

1. Culex pipiens type. Overwinter as adult, eggs laid on water surface; several generations per year. Exception of Culex pipiens molestus in city basements.

   Culex pipiens, C. restuans, C. salinarius, C. territans, Anopheles quadrimaculatus, A. punctipennis, Culiseta morsitans, Uranotaenia sapphirina.

2. Northern Aedes type. Overwinter as eggs; eggs laid on damp mud or earth; one generations a year.

   Aedes abserratus, A. excrucians, A. fitchii, A. aurifer, A. stimulans, A. punctor, many "dark-legged" Aedes, most Aedes canadensis and A. cinereus.

3. Temporaty water Aedes type. Overwinter as eggs; eggs laid on damp mud or earth, or on edge of a "container" or treehole, rock pool; several generations a year.

   A. Salt Marsh Group: Aedes sollicitans in summer but not in spring. Aedes cantator has early spring brood, then subsequent temporary flood broods.

   B. Freshwater Temporary Flood Group: Aedes vexans is the principal species locally. Aedes stictícus in similar conditions in western New England. Psorsphora confinnis rather scarse locally but abundant in Middle U.S. Also locally, Aedes canadensis and A. cinereus of the spring brood may also appear in severe summer re-flooding.

4. Mansonia perturbans type. Overwinter as larvae attached to roots of plants; One irregular generation a year; eggs laid on water surface. Mansonia perturbans

5. Culiseta melanura type. Overwinter as larvae which survive where there is shelter beneath the ice; eggs laid on water surface; several generations a year. Culiseta melanura.

6. Tree Hole and the Rock Pool mosquitoes are Aedes triseriatus and A. atropalpus are similar in life history but select different habitats. A. triseriatus, the tree hole mosquito, is more often found in tires and pails holding water in dense shade. A. atropalpus is common in rock pools of the ledges along the inland streams. Eggs of both species overwinter and produce a spring brood in April - May. Thereafter there is more or less continuous hatching, supposedly because the eggs laid near waters edge either get washed into the water by rain, or the water level rises up to cover them after the rain.

IDENTIFICATION OF SOME MOSQUITO LARVAE

1. Larvae without air tube; palmate hairs on abdomen . . . *Anopheles* sp.

   Larvae with air tube; without palmate hairs 2

2. Air tube broad at base, ending in a point; not like a tube . . . . . *Mansonia perturbans*

   Air tube more or less evenly tapered; two or more times longer than wide 3

3. Head longer than wide; a chitinized plate on 8th segment . . . . . *Uranotaenia sapphirina*

   Head as wide as long, or shorter 4

4. Air tube without pecten . . . . . *Toxorhynchites*, *Orthopodomyia*, *Wyemoia*

   Air tube with pecten 5

5. Anal segment ringed by plate, and pierced by forward tufts of ventral brush . . . . . *Psorophora* sp.

   Anal segment either not ringed, or if ringed, not pierced by the tufts 6

6. Tuft at base of tube and pecten (may have other tufts also) . . . . . *Culiseta* sp. (18)

   Tube without a tuft at base 7

7. Anal segment ringed by plate and several pairs of tufts on tube . . . . . *Culex* sp. (19)

   Anal segment with one pair of tufts; if more, plate is not ringed 8

8. Air tube short; 2 to 2½ times as long as width at base 9

   Air tube longer 12

9. Anal gills shorter than anal segment 10

   Anal gills as long or longer than the anal segment . . 11

10. Anal segment ringed by plate; head hairs single . . . . *Aedes sollicitans*

    Anal segment not ringed by the plate, and head hairs multiple . . . . . *Aedes cantator*

11. Anal gills of uneven length; upper as long as anal segment; lower shorter . . . . . *Aedes triseriatus*

    Anal gills of even length and 1½ times the length of the anal segment . . . . . *Aedes atropalpus*

12. Anal segment ringed by the plate . . . . . *Aedes aberratus*

    Anal segment not completely ringed by the plate 13

13. Antennae enlarged, white colored and as long as head . . . . . *Aedes aurifer*

    Antennae shorter than head, tan colored, enlarged and white 14

14. Pecten uniformly spaced on air tube 15

    One or more of outer spines of pecten more widely spaced. 16

15. Air tube 4 to 5 times longer than wide; head hairs 2 & 3 branched . . . . . .*Aedes fitchii*

    Air tube 3½ to 4 times as long as basal width . . . . .*Aedes canadensis*

16. Air tube yellow-amber in color; 4½ to 5 times longer than base . . . . . *Aedes excrucians*

    Air tube darker gray; 3½ to 4 times longer than base width 17

17. Air tibe 3 to 3½; gills even and as long as segment; head hairs 3 & 2 . . . . . *Aedes vexans*

    Air tube 4 to 4½; gills uneven in length longer than seg., H.H. multiple . . . . . .*Aedes cinereus*

18. (from 6) Tuft at base of pecten and air tube; no other tufts. . . . . .*Culiseta moristans*

    Tuft at base and about a dozen other ventral tufts on tube . . . . . .*Culiseta melanura*

19. (from 7) Air tube 6 to 7 times longer than base width 20

    Air tube 4 to 4½ times basal width 21

20. Air tube yellow-amber; slightly expanded at tip . . . .*Culex territans*

    Air tube dark gray; evenly tapered to tip . . . . . .*Culex salinarius*

21. Air tube 4 to 4½ times base; slightly enlarged before middle; with 3 tufts on tube large and single; gills broad and 2 to 3 times length of seg. . .*Culex restuans*

    Air tube 4 times base; not enlarged before middle; tufts multiple on tube; gills 1 to 1½ length of segment and not unusually broad . . . . . .*Culex pipiens*

KEY TO COMMON GENERA OF ADULT FEMALE MOSQUITOES

1. Palpi about the same length as proboscis . . . . . Anopheles
   Palpi much shorter than proboscis . . . . . See #2

2. Wing scales very broad, dark and light in color; tip of abdomen blunt; proboscis pale-banded . . . . . Coquillettidia (Mansonia)
   Without all three above . . . . . See #3

3. Tip of abdomen pointed; segment 7 of abdomen narrowed, segment 8 much narrowed and retractile; postspiracular bristles present . . . . . See #4
   Tip of abdomen blunt; segment 7 of abdomen not narrowed, segment 8 short but not retractile; postspiracular bristles absent . . . . . See #5

4. Spiracular bristles absent; abdomen with pale scales usually at the base of some segments . . . . . Aedes
   Spiracular bristles absent; abdomen with pale scales usually at the apex of some segments . . . . . Psorophora

5. Spiracular bristles absent . . . . . Culex
   Spiracular bristles present; base of subcostal vein with a tuft of hairs on underside of wing . . . . . Culiseta

IDENTIFICATION OF SOME ADULT FEMALE MOSQUITOES COMMON IN MASSACHUSETTS

1. Palpi as long as proboscis . . . . . .Anopheles sp.
   Palpi only about one fourth as long as proboscis 2

2. Tip of abdomen bluntly rounded, cerci not showing . . . 3
   Tip of abdomen more pointed; the pair of cerci projecting 11

3. A small mosquito with irridescent sapphire markings on thorax . . . . . .Uranotaenia sapphirina
   Thorax without such coloration 4

4. White band near middle of proboscis . . . . . Mansonia perturbans
   Proboscis dark colored 5

5. Tarsi with pale bands . . . . . Culiseta moristans & Culiseta minnesotae
   Tarsi all dark 6

6. Abdomen without bands or patches of lighter color . . . Culiseta melanura
   Abdomen with light colored markings 7

7. Prominent white bands at base of abdominal segments . . 8
   White bands very narrow, or at apex of segments 10

8. White abdominal bands of uniform width; two pale dots on top of thorax . . . . . .Culex restuans
   Abdominal bands narrowed at sides; no pale dots on thorax . . . . . Culex pipiens

9. Basal abdominal bands very narrow, last segment all pale scaled . . . . . Culex salinarius
   Abdominal segments with narrow apical bands . . . . . Culex territans

10. Proboscis with a bright white band near middle . . . . .Aedes sollicitans
    Proboscis without a white band 11

11. Tarsi not banded 12
    Tarsi with at least some narrow bands 15

12. A dark colored mosquito with silvery white areas on thorax . . . . . Aedes triseriatus
    Thorax without silvery white coloration 13

13. Thorax with dark median stripe, with golden scales each side . . . . . Aedes aurifer
    Thorax not so marked 14

14. Abdomen with prominent basal bands . . . . . Aedes abserratus

    Basal bands absent, but sides of segments white; brown patches behind the eyes . . . . . .Aedes cinereus

15. Hind tarsi with white bands on both sides of the joints 16

    Hind tarsi with bands one side of joints 17

16. Abdomen with basal bands fairly uniform in width . . . Aedes atropalpus

    Abdomen with very narrow basal band widening to side patches . . . . . Aedes canadensis

17. Tarsal white bands very narrow, not as wide a tarsi . .18

    Tarsal white bands much wider than width of tarsi . . .Aedes excrucians & Aedes fitchii

18. Abdominal bands "B" shaped notched in middle, last abdominal segments pale scaled . . . . . .Aedes cantator

C. Breeding Areas

Anywhere water is capable of being trapped is a likely place for mosquitoes to breed. It is estimated that 7,000 mosquitoes can potentially be found in one square foot of water and a 10 X 15 pool is capable of producing one million adults.

Common areas for mosquito breeding are:

catch basins	boats
clogged bodies of water	cemetary urns
construction depressions	clogged rain gutters
flooded flower pots	rain barrels
holy water fonts in churches	hoof prints
public dumps	tin cans
bird baths	automobile tires
snow pools	swamps
swimming pool covers	tree holes
cisterns	tire tracks

D. Diseases

1. Malaria

Three hundred and sixty-four million people live in malarial areas where no control program is presently being used. Because of control programs, malaria nears eradication in the U.S.

The disease is caused by a protozoan that invades the red corpuscles of the blood. There are four known species of malarial parasites. Each produce a distinct type of malaria: Plasmodium vivax - causative agent of benign tertian or vivax malaria; Plasmodium malariae - quartan malaria; Plasmodium falciparum - agent of malignant, subtertian, pernicious, or aestivoautumnal malaria; and Plasmodium ovale - ovale malaria.

Only a part of a particular group of mosquitoes (Genus - Anopheles) can effect the transfer of malaria between humans. One vector species, Anopheles quadrimaculatus occurs throughout the U.S. The mosquito which occurs here in N.H. is capable of spreading malaria if it has access to any malarial protozoans. Mosquitoes obtain the protozoa only by feeding on the blood of a person suffering from malaria.

Malaria can be prevented from becoming established by: 1) isolating malarial cases from anopheline mosquitoes; 2) controlling mosquitoes to keep anopheline populations low.

2. Encephalitis

Encephalitis is a disease which affects the central nervous system. Encephalitis is designated as primary or arthropod-borne encephalitis if the disease is transmitted to man or animal by an arthropod vector.

Arthropod-borne encephalitis should be suspected for any case of encephalitis which occurs in July, August, or September.

Four common types of arthropod-borne encephalitic infections found in the U.S. are: California encephalitis (CE), eastern encephalitis (EE), St. Louis encephalit (SLE), and western encephalitis (WE). Each is caused by a different virus and each has a different mortality rate, degree of severity, and susceptible age group.

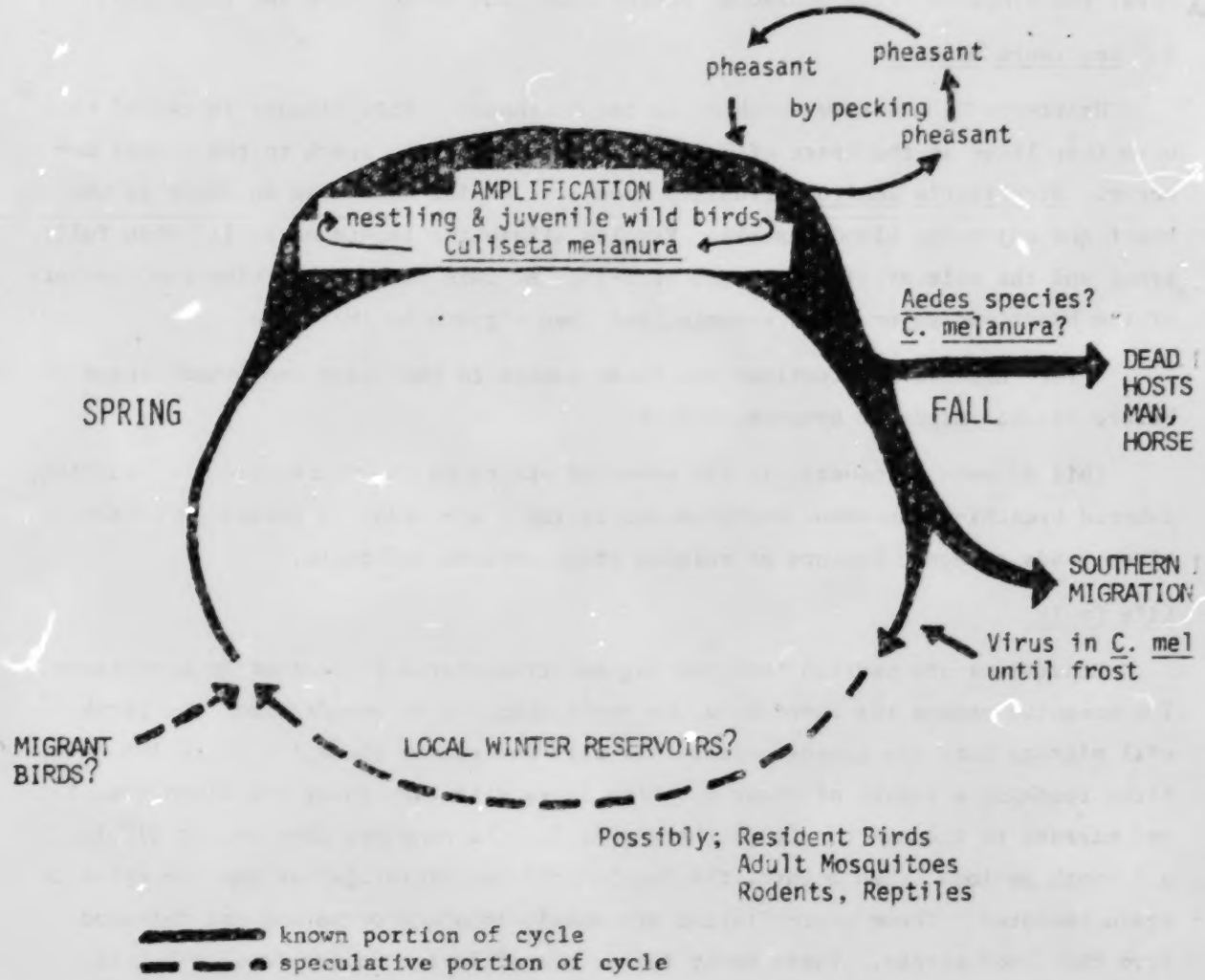
Eastern equine encephalitis has been present in N.H. for many years. Recent outbreaks (73) have brought our attention back to control measures and survey. The cycle of EEE (eastern equine encephalitis) is as follows: Culiseta melanura, a fresh water mosquito found chiefly in swamps, transmits the virus from bird to bird during the warmer months. Occasionally, the virus is transmitted to flocks of partridges pheasants, where it is passed from bird to bird by direct contact (pecking) rather than mosquito bites.

EEE virus may also be transmitted from bird to horse and from bird to man by mosquitoes. Horses and man are termed "dead end hosts" which means that the level of virus circulating in the blood stream is too low for a mosquito to pick up and transmit to another host.

The following mosquito species, due to their widespread occurence in our state and their ability to carry encephalitis to man, should be considered in any control program:

Aedes canadensis
Aedes triseriatus
Aedes vexans
Culex restuans
Culex salinarius
Culex territans
Culiseta melanura
Culex pipiens
Mansonia perturbans

EE VIRUS CYCLE IN TEMPERATE REGION



3. Filariasis

Filariasis is caused by minute roundworms which live in the blood and lymphatic system of man. This disease is believed to be responsible for a number of organic disturbances including elephantiasis, which is characterized by enlargements of the legs, arms, or other parts of the body.

4. Dengue

Dengue is also a mosquito-related, noncontagious disease of low mortality sometimes called "breakbone fever". The causative agent is transmitted by mosquitoes, the symptoms being headache, aching eyes, and severe body and limb pain.

5. Heartworm Disease

Heartworm is a serious problem in the northeast. This disease is caused by a worm that lives in the heart of dogs. If left untreated, death to the animal may occur. Dirofilaria immitus lives and does most of its damage as an adult in the heart and adjoining blood vessels. Females attain the length of 10-14" when fully grown and the male attains a length of 5-7". At this stage, they clog the chambers of the heart and major blood vessels, and then migrate to the lungs.

Severe heartworm infections can cause damage to the heart and other organs before visible signs or symptoms appear.

This disease is usually in its advanced stages by the time symptoms - coughing, labored breathing, uncommon weakness and tiring - are seen. A severe infection often leads to heart failure or related complications and death.

Life Cycle

Heartworms are carried from one dog and transmitted to another by mosquitoes. The mosquito passes the larva into the dog's skin. Upon penetration, the larva will migrate into the tissue beneath the skin and remain there for 90 to 100 days. After reaching a length of about 3 ", the larva will then enter the blood vessel and migrate to the heart. It is there that it will complete development within a 5 month period. When mature, the female produces microfilariae and the cycle is again repeated. These microfilariae are small, immature worms and are released into the blood stream. These newly formed microfilariae do not develop but remain in the blood stream up to 3 years. They can only develop in the body of a mosquito and then transferred to another host. As the mosquito draws blood from

it's host, several microfilariae are ingested where they undergo a transformation in about 14 to 21 days. Adults live for approximately five years.

Dogs of all breeds are susceptible.

E. Surveys

An important step in proper mosquito control is that of survey. Surveys provide such information as:

1. Species and their abundance in a given area.
2. Locations of all temporary and permanent bodies of water.
3. Breeding areas and their locations.
4. Major resting places for adults.
5. Hibernation site locations.

Adult surveys are conducted to:

1. Identify the problem areas.
2. Determine whether or not the numbers are enough to cause annoyance or if any disease organisms are present in the existing populations.
3. Evaluate any prior control measures.

There are three basic types of surveys that should be performed. The first (1) is the use of light traps. Each trap should be checked on a daily basis with all species being identified. Unfortunately, not all species are attracted by light so this method must be supplemented with another measure.

The second (2) measure is biting or landing counts. This method is used to sample species that feed on man. This is done by collecting the mosquitoes as they actually land on a person to feed. They should be collected, identified, and counted. Sampling of this type should be done at various times of the evening for some mosquitoes feed at sundown, others during the late evening and still others feed during late evening and dawn.

Larval surveys (3) should be employed in order to locate prime breeding areas. A dipper is used to collect the larvae as they rest on the water's surface. By skimming the dipper among the vegetation floating at the water's surface, one can collect Anopheles larvae. Psorophora and Aedes larvae are easily frightened and must be collected by plunging the dipper into the water quickly before they have

the chance to dive to the bottom of the pool. Mansonia larvae cannot be collected by dipping for they attach themselves to plant roots, therefore, one must uproot the vegetation in order to collect these larvae. Aedes triseriatus can be collected by siphoning tree water into a container.

F. Control

There are 3 basic control measures that are currently being used:

I. Biological Control (Use of natural enemies)

Predators

A. Vertebrata

1. Fish predaceous on larvae

Gambusia affinis (mosquito fish)
Poecilia reticulata (guppy)
Nothobranchius spp. (annual fish)
Cynolebias spp. (annual fish)
Gasterosteus aculeatus (three-spined stickleback)
Fundulus spp.
Cyprinodon spp.
Lucania spp.

2. Fish indirectly beneficial to biological control (may also feed on larvae)

Tilapia mossambica (weed and algae feeders)
Tilapia zillii (weed and algae feeders)
Tilapia hornorum (weed and algae feeders)

3. Birds
Ducks (various species feed on larvae)
Sandpipers (feed on larvae and pupae)
Killdeer (feed on larvae and pupae)
Blackbirds (feed on larvae and pupae)

4. Bats (several species feed on adult mosquitoes)

B. Invertebrata

1. Insecta
Odonata (damsel and dragonflies)
Hemiptera (water bugs)
Corixidae (water boatmen)
Notonectidae (back swimmers)
Belostomatidae (giant water bug)
Coleoptera (beetle)
Dytiscidae (predaceous water beetles)
Hydrophilidae (water scavengers)
Hymenoptera
Ants (predaceous on eggs and pupae)
Diptera
Toxorynchites spp. (predaceous on larvae)

2. Other

Coelenterata
Hydra species
Araneae
Spiders

Parasites

A. Viruses
B. Bacteria
   1. Bacillus thuringiensis
   2. Bacillus sphaericus
C. Fungi
   1. Langenidium giganteum
D. Nematodes
   1. Reesimermis nielseni

II Cultural Control

A. Ditching
B. Fresh Water Drainage
C. Changing Breeding Areas
D. Salt Marsh Impoundment: Creation of a shallow lake 12-18" deep. This is created by diking and flooding a given area and also provides habitat for waterfowl and other wildlife.

Note on Water Management: All mosquitoes need water in which to complete their development. Their eggs will not hatch, and their larvae and pupae cannot live without it. If one simple answer were available to the elimination of mosquitoes, it would be to eliminate all water in which mosquitoes can breed.

Fill in ditches and low areas or drain swampy land where possible.

Mosquitoes can complete their life cycle from egg to adult in less than seven days. Water allowed to accumulate for this length of time in tin cans, old tires, small wading pools, boats, tree holes, clogged rain gutters, etc. can provide a breeding place for mosquitoes. These breeding places must be eliminated.

Clean out vegetation from the edges of ponds, lakes, drainage ditches and streams. Many mosquitoes breed in the shallow water along the edges of bodies of water and are protected from predators by the plant growth present there. If the banks around a pond can be steepened, mosquito breeding will be reduced.

III. Chemical Control

A. Adulticide
   1. Non-thermal fogging - ground ultra low volume
      a. Premium grade malathion 95%
         Discharge rates: 2.1 fl. oz/min @ 5 mph
                          4.3 fl. oz/min @ 10 mph

b. Pyrethrum ULV insecticide 5%
Discharge rate: 2-2.25 fl oz/min @ 5 mph
4-4.5 fl. oz/min @ 10 mph

2. Mist spraying
a. Use 2-3 gals. malathion (57% E) in 148-149 gals H_2O

3. Aerial Spraying Ultra Low Volume (ULV)
a. Apply Dibrom 14 @ one fl. oz/A
b. Malathion 95% - Use 3-3.2 fl. oz/A

4. Thermal Fogging
a. Use 6 gallons of malathion 57 E plus 2 quarts of Thiosperse* in 94 gallons of fuel oil #2
b. Use one gallon of Dibrom 14 plus 2 gallons of Ortho Additive D* in 99 gallons of fuel oil #2
c. Use 3.2 gallons of malathion 95 plus one quart of Thiosperse* in 96 gallons of fuel oil #2

5. Sprays for Use of Homeowners around Yard and Patio
a. Use 5 tablespoons of malathion 57% E in 1 gallon of water. Apply with compressed air sprayer.
b. Pyrethrins, synthetic pyrethrin formulations or dichlorvos as aerosols in pressurized containers.

B. Larvicide (Control of larvae of mosquitoes)

1.	Abate 4 E	1.5 to 1.5 fl. oz/A in sufficient water for good coverage. Apply with ground or aerial equipment. (Do Not Mix with Fuel Oil)
2.	Abate 2% Granular	Shallow ponds - 2.5-5 lbs/A Swamps - 10 lbs/A Highly polluted water - 25 lbs/A
3.	Abate 1% Granular	Shallow Ponds - 5-10 lbs/A Swamps - 10-20 lbs/A Highly polluted water - no recommendation
4.	Flit MLO	1-5 gal. per acre, depending on water temperature and emergent vegetation. Applied to water surface.

* This material is a sludge inhibitor. It should be thoroughly dissolved in the fuel oil before adding the insecticide. This is not necessary if kerosene is used.

G. N.H. State Regulations of Importance

Definitions:

1. "Surface waters or their tributaries used for Public Water Supply":

Those lakes, ponds, rivers, streams, or other open waters designated and delimited by the Water Pollution Commission as sources of Public Water Supply.

2. "Watershed of Public Water Supply":

That area which contributes surface water runoff either directly to a surface source of Public Water Supply or to the reservoir, lake, pond, river, stream, ditch, watercourse, or intermittent rivulet or other open waters that at any time flow directly or ultimately into designated sources of Public Water Supply.

3. "Drift":

The airborne movement of pesticides resulting from a pesticide application such as to carry pesticides beyond the target pest area.

4. "Pesticide":

Any chemical or biological agent used to control a pest. The term pesticide shall include but not be limited to the following materials: acaricides (miticides) insecticides, nematocides, herbicides (weed & brush killers, dessicants and defoliants), fungicides, molluscicides, repellents, algaecides, rodenticides, disinfectants, and fumigants.

5. "Disposal":

Discarding, open burning, or incineration of excess or unusable pesticide materials and discarding of pesticide containers or the sale or transfer of ownership of pesticide containers for use other than to contain pesticides.

General Regulations:

1. All pesticides or formulations thereof, used or applied in New Hampshire must be registered with the N.H. Department of Agriculture as provided for in the Economic Poisons Law, RSA Chapter 438.

2. Registered pesticides are to be applied in strict accordance with recommendations from legally constituted authorities, except for experimental work. . .

3. Pesticide Anti-Siphon: All pest control equipment using pesticides and drawing water from the surface waters of the State as defined in RSA 149 shall have an effective anti-siphon device approved by the Board to prevent back flow.

4. All on-highway vehicles when used for business purposes for the commercial application of pesticides by commercial applicators to be identified by lettering and or signs that will identify the applicators business together with license number; and further that said lettering of business name and license number shall not be less than two inches in height.

Restrictions on the Application of Pesticides by Commercial Applicators and Permittees

1. No pesticide shall be applied to Public Water Supplies or their tributaries except by legally established water supply entities or their agents as authorized by the Water Pollution Commission. Pesticide applications to land near or adjacent to Public Water Supplies shall be made in such a manner that no pesticides drift or flow into such water supplies.

2. No pesticide application may be made within 400 feet of gravel packed wells used for Public Water Supply or within 250 feet of other wells so used, unless materials and methods to be employed have been approved by the Board upon the recommendation of the Water Pollution Commission.

3. a. Pesticide applications shall not be made on the watershed of a Public Water Supply unless such applications have been approved by the Board upon the recommendation of the Water Pollution Commission.

b. No pesticide shall be applied to woodland areas exceeding 50 acres without prior approval of the Board upon recommendations of the State Forester and Director of Fish and Game.

4. Pesticide applications shall not be made in a watershed or on marshland for control of forest insects, mosquitoes, or black flies unless such applications have been approved by the Board.

. . .

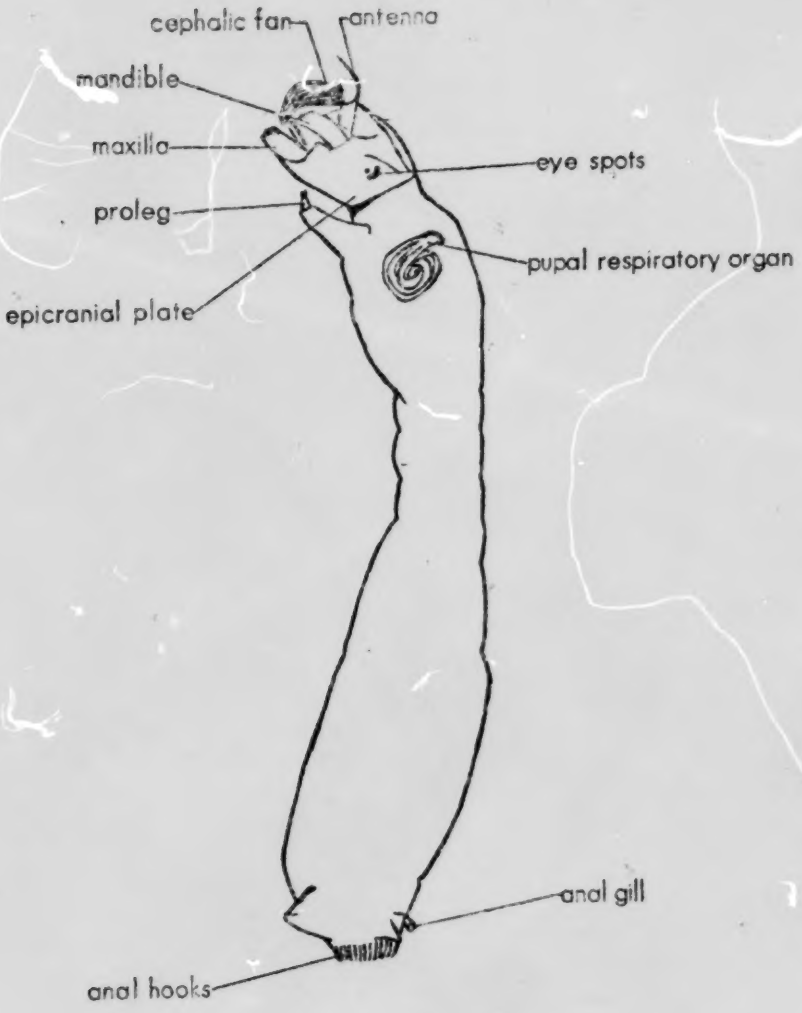
7. Pesticide applications to any surface waters of the state for the control of aquatic nuisances or for any other reason shall not be made unless such applications have been approved by the Board upon recommendation of the Water Pollution Commission.

8. No application of pesticides by means of aircraft shall be made within the State without prior approval of the Board or its designated representative after consultation with the affected agencies.

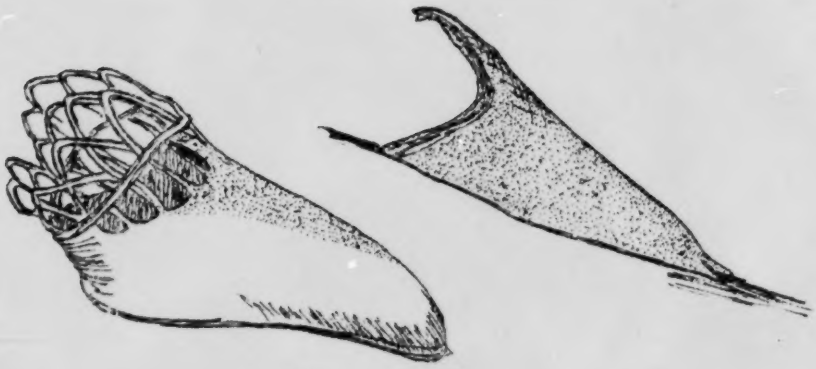
Section 2: Black Flies



ADULT BLACK FLY



MATURE LARVA



PUPAL COCOONS

A. Introduction

Black flies are small (1-5 mm), humpbacked insects belonging to the Order - Diptera, Family - Simuliidae. They are blood-sucking insects, occuring in enormous numbers in late spring and early summer. With mouthparts similar to those of the horsefly, their bite can be extremely painful. As the female bites, a venom is injected into the skin of its host resulting in a swelling and numb-soreness. There are reports that domestic animals and humans have been killed as a result of a black fly bite.

Some species of black flies are known vectors of filarial worms and onchocerciasis. These diseases can cause blindness in humans in Mexico, Central America, and Africa.

B. Description of Life Stages

Egg

Eggs are smooth, whitish-yellow in color, and asymmetrical in shape due to a bulge on one side (.2-.4 mm). Before hatching, the color changes to a near black. They can be found in masses on vegetation, rocks, or on stream bottoms.

Larva

Larvae are always found in flowing water. They have completely developed head capsules. Mouthparts are modified in a horizontal position for chewing. A pair of large "fan-shaped" appendages are also found on the head capsule. These appendages are used for trapping food particles in the water. The thorax has a pair of pseudopods which are closely fused to form the proleg. The entire body is somewhat cylindrical except for posterior swelled area. The end segment of the abdomen has a sucking disk with a series of small hooks. These hooks allow the larvae to anchor themselves to rocks or debris in swift flowing streams.

Pupa

The pupa can be found attached to debris in swift flowing water with its head downstream. The entire body is in the shape of a slipper or cone. The surface of the cephalothorax is usually smooth except for a few species. The thorax has a respiratory organ on each side. These organs are used in the identification of certain species. The abdomen has rows of recurved hooks on some species.

Adult

The adult is a small, dark colored fly. Antennae are located between the eyes and are 11 segmented (rarely 9-10). There is a pair of compound eyes but no simple eyes are present. In most species, the mouthparts are modified for cutting and sucking. The thorax has a "hump-backed" appearance, from which the black fly gets the name, "Buffalo Gnat."

C. Life Cycle

Egg laying of black flies differs with many species. Some eggs are deposited singly into the stream, others in masses on vegetation overhanging a water source and some species deposit their eggs in long filaments. Each female black fly lays 150 to 450 eggs in her lifetime. Most species overwinter in the egg stage. Hatching occurs in as short of a time as 2½ days and as long as seven months. As the eggs mature, they darken in color from white to brown. Larvae are always found in running water. Habitats may vary from large streams that are permanent to small temporary streams. They are also found below dams, large pools and lake outlets. The minimal larval development period is twelve days during which time it molts six times. Pupation occurs after the sixth molt. They can be found attached to the same surfaces as the larvae. The open end of the pupal case will face downstream. The pupal stage ranges from two days to three weeks. This varying length of time is mainly due to water temperatures and species.

D. Control in New Hampshire

Studies are presently being conducted by the U.N.H. Department of Entomology on the use of certain insecticides for the control of black flies in N.H. There are presently no registered chemicals for black fly control in N.H.

Section 3: Calculation Methods and Conversions For Pesticide Application

USEFUL CALCULATION METHODS TO DETERMINE VARIOUS APPLICATION CRITERIA

1. To determine the amount of active ingredient needed to mix in the spray tank:

$$\text{Number of gallons or pounds} = \frac{\text{number of acres to be sprayed} \times \text{pounds active ingredient required per acre}}{\text{pounds active ingredient per gallon or per pound}}$$

2. To determine the amount of pesticide needed to mix a spray containing a certain percentage of the active ingredient:

$$\text{Number of gallons or pounds} = \frac{\text{gallons of spray desired} \times \%\text{ active ingredient wanted} \times 8.345^{*}}{\text{pounds active ingredient per gallon or per pound} \times 100}$$

3. To determine the percent active ingredient in a spray mixture:

$$\text{Percent} = \text{pounds or gallons of concentrate used (not just active ingredient)} \times \frac{\%\text{ active ingredient in the concentrate}}{\text{gallons of spray} \times 8.345}$$

4. To determine the amount of pesticide needed to mix a dust with a given percent active ingredient:

$$\text{Pounds material} = \frac{\%\text{ active ingredient wanted} \times \text{pounds mixed dust wanted}}{\%\text{ active ingredient in pesticide used}}$$

5. To determine the size of pump needed to apply a given number of gallons per acre:

$$\text{Pump capacity} = \frac{\text{gallons per acre desired} \times \text{boom width (feet)} \times \text{mph}}{495}$$

6. To determine the nozzle capacity in gallons per minute at a given rate per acre and miles per hour:

$$\text{Nozzle capacity} = \frac{\text{gallons per acre} \times \text{nozzle spacing (inches)} \times \text{mph}}{5940}$$

7. To determine the acres per hours sprayed:

$$\text{Acres per hour} = \frac{\text{swath width (inches)} \times \text{mph}}{100}$$

8. To determine the rate of speed in miles per hours:
   First measure off a distance of 300 to 500 feet; then measure in seconds the time it takes the tractor to go the marked-off distance.

$$\text{mph} = \frac{.682 \times \text{distance}}{\text{seconds to travel distance}}$$

*8.345 is the weight in pounds of one gallon of water.

9. To determine the nozzle flow rate:
   First note the time in seconds necessary to fill a pint jar from a nozzle.
   Gallons per minute per nozzle = $\frac{7.5}{\text{seconds to fill jar}}$

10. To determine the gallons per minute per boom:
    Calculate the gallons per minute per nozzle and multiply by the number of nozzles.

11. To determine the gallons per acre delivered:
    Gallons per acre = $\frac{5940 \times \text{gallons per minute per nozzle}}{\text{nozzle spacing (inches)} \times \text{mph}}$

12. To determine the acreage sprayed per hour:
    Acre sprayed per hour = $\frac{\text{boom width (feet)} \times \text{mph}}{12}$
    (This allows 30% of the time for filling, turning, etc.)

13. Sprayer Tank Capacity
    For cylindrical tanks:
    Number of gallons = length in inches x diameter squared x .0034
    For elliptical tanks:
    Number of gallons = length in inches x short diameter x long diameter x .0034
    For rectangular tanks:
    Number of gallons = length x width x depth x .004329

14. To determine the acres in a given area:
    Number of acres = length in feet x width in feet x .000023

15. To calibrate a knapsack sprayer:
    Spray a measured square rod area for one minute and catch the spray from the nozzle or nozzles.
    Gallons per acre = 20 x pints caught in one minute

AREA AND VOLUME CONVERSIONS

LINEAR MEASURE

1 foot = 12 inches
1 yard = 3 feet
1 rod = 5.5 yards = 16.5 feet
1 mile = 160 rods = 1760 yards = 5280 feet

SQUARE MEASURE

1 square foot = 144 square inches
1 square yard = 9 square feet
1 square rod = 272.25 square feet = 30.25 square yard
1 acre = 43,560 square feet = 4840 square yards = 160 square rods
1 square mile = 640 acres
1 acre = 209 square feet

CUBIC MEASURE

1 cubic foot = 1728 cubic inches = 29.922 quarts = 7.48 gallons
1 cubic yard = 27 cubic feet
1 cubic foot of water = 62.5 pounds

LIQUID CAPACITY MEASURE

1 tablespoon = 3 teaspoons
1 fluid ounce = 2 tablespoons
1 cup = 8 fluid ounces
1 pint = 2 cups = 16 fluid ounces
1 quart = 2 pints = 32 fluid ounces
1 gallon = 4 quarts = 8 pints = 128 fluid ounces

WEIGHT MEASURE

1 pound = 16 ounces
1 hundredweight = 100 pounds
1 ton = 2000 pounds = 20 hundredweight

METRIC MEASURE

1 gram = .035 ounce
1 kilogram = 2.2 lb
1 quintal = 100 kg = 221 lb
1 metric ton = 1000 kg = 2,205 lb
1 hectare = 2.5 acres
1 meter = 39.4 inches
1 kilometer = .6 mile

TEMPERATURE CONVERSIONS

^{o}F	^{o}C	^{o}F	^{o}C
32.0	0	78.8	26
35.6	2	82.4	28
39.2	4	86.0	30
42.8	6	89.6	32
46.4	8	93.2	34
50.0	10	96.8	36
53.6	12	100.4	38
57.2	14	104.0	40
60.8	16	122.0	50
64.4	18	140.0	60
68.0	20	158.0	70
71.6	22	176.0	80
75.2	24	194.0	90
		212.0	100

IMPORTANT CONVERSION FORMULAE

volume of a sphere = diameter ^{3} x .5236
diameter = circumference x .31831
area of a circle = diameter ^{2} x .7854
area of an ellipse = wide diameter x narrow diameter x .7854
volume of a cone = area of base x $\frac{\text{height}}{3}$

pressure in pounds per square inch = height in feet x .434
parts per million = percentage x 10,000
percentage = $\frac{\text{parts per million}}{10{,}000}$

The formula for conversion from Centigrade to Fahrenheit is:

$$^{o}F = \left(\frac{^{o}C \times 9}{5}\right) + 32 \quad \text{or} \quad ^{o}F = (^{o}C \times 1.8) + 32$$

The formula for conversion from Fahrenheit to Centigrade is:

$$^{o}C = (^{o}F - 32) \times \frac{5}{9} \quad \text{or} \quad ^{o}C = (^{o}F - 32) \times 0.5556$$

CONVERSION FACTORS

To Convert from	To	Multiply by
cubic feet	gallons	7.48
cubic feet	liters	28.3
gallons	milliliters	3785
grams	pounds	.0022
grams/liter	parts/million	1000
grams/liter	pounds/gallon	.00834
liters	cubic feet	.0353
milligrams/liter	parts/million	1.0
milliliters	gallons	.0026
ounces	grams	28.35
parts/million	grams/liter	.001
parts/million	pounds/million gallons	8.34
pounds	grams	453.59
pounds/gallon	grams/liter	111.83

CONVERSIONS FOR RATES OF APPLICATION

1 ounce per square foot	= 2722.5 pounds per acre
1 ounce per square yard	= 302.5 pounds per acre
1 ounce per 100 square feet	= 27.2 pounds per acre
1 pound per 100 square feet	= 435.6 pounds per acre
1 pound per 1000 square feet	= 43.6 pounds per acre
1 gallon per acre	= 1/3 ounce per 1000 square feet
5 gallons per acre	= 1 pint per 1000 square feet
100 gallons per acre	= 2.5 gallons per 1000 square feet
	= 1 quart per 100 square feet
100 pounds per acre	= 2.5 pounds per 1000 square feet

APPLICATION RATES OF ACTIVE INGREDIENT PER ACRE FOR VARIOUS CONCENTRATIONS OF EMULSIFIABLES, WETTABLES, AND DUSTS

Pounds of active chemical recommended per acre:									
1/8	1/4	1/2	3/4	1	1 1/2	2	2 1/2	3	5
Amount of formulation needed to obtain the above amounts of active chemical for:									
10%-12% Emulsion Concentrate (contains 1 pound chemical per gallon)									
1 pt	1 qt	2 qt	3 qt	1 gal	1 1/2 gal	2 gal	2 1/2 gal	3 gal	5 gal
15%-20% Emulsion Concentrate (contains 1 1/4 pounds chemical per gallon)									
1/3 qt	2/3 qt	1 1/3 qt	2 qt	2 2/3 qt	1 gal	1 1/3 gal	1 2/3 gal	2 gal	3 2/5 gal
25% Emulsion Concentrate (contains 2 pounds chemical per gallon)									
1/2 pt	1 pt	1 qt	3 pt	2 qt	3 qt	1 gal	5 qt	1 1/2 gal	2 1/2 gal
40%-50% Emulsion Concentrate (contains 4 pounds chemical per gallon)									
1/4 pt	1/2 pt	1 pt	1 1/2 pt	1 qt	3 pt	2 qt	5 pt	3 qt	5 qt
60%-65% Emulsion Concentrate (contains 6 pounds chemical per gallon)									
1/6 pt	1/3 pt	2/3 pt	1 pt	1 1/3 pt	1 qt	2 2/3 pt	3 1/3 pt	2 qt	3 1/3 qt
70%-75% Emulsion Concentrate (contains 8 pounds chemical per gallon)									
1/8 pt	1/4 pt	1/2 pt	3/4 pt	1 pt	1 1/2 pt	1 qt	2 1/2 pt	3 pt	2 1/2 qt
15% Wettable Powder									
3/4 lb	1 1/2 lb	3 1/3 lb	5 lb	6 2/3 lb	10 lb	13 1/2 lb	16 2/3 lb	20 lb	33 1/3 lb
25% Wettable Powder									
1/2 lb	1 lb	2 lb	3 lb	4 lb	6 lb	8 lb	10 lb	12 lb	20 lb
40% Wettable Powder									
5 oz	10 oz	1 1/4 lb	1 7/8 lb	2 1/2 lb	3 3/4 lb	5 lb	6 1/4 lb	7 1/2 lb	12 1/2 lb
50% Wettable Powder									
1/4 lb	1/2 lb	1 lb	1 1/2 lb	2 lb	3 lb	4 lb	5 lb	6 lb	10 lb
75% Wettable Powd									
1/6 lb	1/3 lb	2/3 lb	1 lb	1 1/3 lb	2 lb	2 2/3 lb	3 1/3 lb	4 lb	6 2/3 lb
80% Wettable Powder									
2 1/2 oz	5 oz	5/8 lb	15/16 lb	1 1/4 lb	1 7/8 lb	2 1/2 lb	3 1/8 lb	3 3/4 lb	6 1/4 lb
1% Dust									
12 1/2 lb	25 lb	50 lb	75 lb	100 lb	150 lb	200 lb	250 lb	300 lb	500 lb
5% Dust									
2 1/2 lb	5 lb	10 lb	15 lb	20 lb	30 lb	40 lb	50 lb	60 lb	100 lb
10% Dust									
1 1/4 lb	2 1/2 lb	5 lb	7 1/2 lb	10 lb	15 lb	20 lb	25 lb	30 lb	50 lb

QUANTITIES OF PESTICIDE NECESSARY TO ACHIEVE
THE SAME CONCENTRATION IN VARIOUS QUANTITIES OF WATER

WATER	PESTICIDE (Powder)				
100 gal	1 lb	2 lb	3 lb	4 lb	5 lb
50 gal	.5 lb	1 lb	1.5 lb	2 lb	2.5 lb
12 1/2 gal	4 oz	8 oz	12 oz	1 lb	1.25 lb
6 1/4 gal	2 oz	4 oz	6 oz	8 oz	10 oz
3 1/8 gal	1 oz	2 oz	3 oz	4 oz	5 oz
1 gal	4.5 g	9.1 g	13.6 g	18.1 g	22.7 g
1 liter	1.2 g	2.4 g	3.6 g	4.8 g	6.0 g
1 qt	1.1 g	2.3 g	3.4 g	4.5 g	5.7 g

WATER	PESTICIDE (Liquid)				
100 gal	.5 pt	1 pt	1 qt	2 qt	1 gal
50 gal	.25 pt	.5 pt	1 pt	1 qt	2 qt
25 gal	2 oz	4 oz	8 oz	1 pt	1 qt
12 1/2 gal	1 oz	2 oz	4 oz	8 oz	1 pt
6 1/4 gal	.5 oz	1 oz	2 oz	4 oz	8 oz
3 1/8 gal	.25 oz	.5 oz	1 oz	2 oz	4 oz
1 gal	.75 oz	1.5 oz	3 oz	6.25 oz	12.5 oz
1 liter	0.625 ml	1.25 ml	2.5 ml	5.0 ml	10.0 ml
1 qt	.2 oz	4 oz	8 oz	1.5 oz	3.2 oz

* fluid oz

CONCENTRATIONS OF CHEMICALS IN SOIL

Amount of Chemical Required to Give Indicated Concentration in Soil*

Parts per Million Concentration in Soil	1 Square Foot To Soil Depth Of:			1000 Square Feet To Soil Depth Of:			1 Acre (43,560 sq ft) Soil Depth Of:		
	1 inch	4 inches	12 inches	1 inch	4 inches	12 inches	1 inch	4 inches	12 inches
1	-	.01 g	.04 g	.11 oz	.43 oz	1.3 oz	0.3 lb	1.2 lb	3.5
10	-	0.1 g	0.4 g	1.1 oz	4.3 oz	13 oz	3 lb	12 lb	35 lb
50	0.2 g	0.7 g	2 g	5.4 oz	1.3 lb	4 lb	14 lb	58 lb	175 lb
100	0.38 g	1.3 g	4 g	10.8 oz	2.7 lb	8 lb	29 lb	117 lb	350 lb
150	0.5 g	2.0 g	6 g	1.0 lb	4 lb	12 lb	44 lb	175 lb	525 lb
200	0.8 g	2.6 g	8 g	1.3 lb	5.3 lb	16 lb	58 lb	233 lb	700 lb
500	1.7 g	6.7 g	20 g	3.3 lb	13.3 lb	40 lb	146 lb	583 lb	1750 lb
1000	3.4 g	13.4 g	40 g	6.7 lb	26.7 lb	80 lb	292 lb	1167 lb	3500 lb

* Assumes soil specific gravity of 1.3, equivalent to 81 pounds of dry soil per cubic foot. Modify amounts of chemical proportionately for higher or lower specific soil gravity.

SPRAY CONCENTRATION CONVERSIONS

Ounces Per 100 Gallons	Parts per Million	Percent Solution	Grams per 100 liters
2/3	50	.005	5
1	75	.0075	7.5
1 1/3	100	.01	10
2	150	.015	15
2 2/3	200	.02	20
3 1/3	250	.025	25
4	300	.03	30
5 1/3	400	.04	40
6 2/3	500	.05	50
8	600	.06	60
9 1/3	700	.07	70
10 2/3	800	.08	80
12	900	.09	90
13 1/3	1000	0.10	100
16	1200	0.12	120
20	1500	0.15	150
24	1800	0.18	180

PARTS PER MILLION RELATIONSHIPS

1 gram in 100 milliliters	=	10,000 ppm	=	1.0%
1 gram in 1 liter	=	1,000 ppm	=	0.1%
1 gram in 10 liters	=	100 ppm	=	0.01%
1 gram in 100 liters	=	10 ppm	=	0.001%
1 gram in 1000 liters	=	1 ppm	=	0.0001%
1 gram in 10,000 liters	=	0.1 ppm		

100 parts per million = 1.33 ounces per 100 gallons
OR
0.1 grams per liter
1 gram per 10 liters
10 grams per 100 liters
100 grams per 1000 liters

METRIC EQUIVALENTS

100 liters = 105.8 quarts = 26.45 gallons
100 gallons = 378.5 liters
1 ounce = 28.35 grams
1 gram = 0.035 ounces
10 grams = 0.35 ounces
100 grams = 3.35 ounces

CONVERSION TABLE FOR SMALL-AREA SPRAYING

Rate Per Acre	Rate Per 1,000 Square Feet	Rate Per 100 Square Feet	
1 lb	0.35 oz	0.25 tsp	Dry Materials
2	0.7	0.50 tsp	
3	1.1	0.75 tsp	
4	1.4	1.00 tsp	
5	1.8	1.25 tsp	
6	2.1	1.50 tsp	
8	2.8	1.75 tsp	
10	3.7	2.00 tsp	
20	7.3	0.73 oz	
40	14.0	1.4 oz	
50	18.0	1.8 oz	
100	37.0	3.7 oz	
200	73.0	7.3 oz	
300	110.0	11.0 oz	
400	147.0	14.7 oz	
500	184.0	18.4 oz	
1 pt	0.36 fl oz	0.25 tsp	Liquid Materials
1 qt	0.72 fl oz	0.50 tsp	
1 gal	2.9 fl oz	2.00 tsp	
2 gal	5.9 fl oz	4.00 tsp	
3 gal	8.8 fl oz	2.00 Tbsp	
5 gal	14.7 fl oz	3.00 Tbsp	
10 gal	29.4 fl oz	6.00 Tbsp	
15 gal	2.8 pt	9.00 Tbsp	
20 gal	3.7 pt	12.00 Tbsp	
25 gal	2.3 qt	15.00 Tbsp	
50 gal	4.6 qt	1.84 cups	
75 gal	6.9 qt	2.76 cups	
100 gal	9.19 qt	3.67 cups	
200 gal	18.37 qt	7.35 cups	

Dry: 1 lb/100 gal = 1 oz/6 1/4 gal = 1/2 oz/3 gal = 4.5 gm/gal
Liquid: 1 pt/100 gal = 1 fl oz/6 1/4 gal = 1/2 fl oz/3 gal = 1 tsp/gal
1 qt/100 gal = 10 tsp/5 gal = 2 Tbsp/3 gal = 2 tsp/gal
1 gal/100 gal = 3/4 cup + 4 tsp/5 gal = 1/2 cup/3 gal = 8 tsp/gal

QUANTITIES OF PESTICIDE IN LIQUID FORMULATION FOR EQUIVALENCE BETWEEN 100 GALLONS AND 1 GALLON

Pounds of Active Chemical Per Gallon of Concentration	Teaspoons per Gallon To Equal 1 Pound per 100 Gallons Of Dilute Spray
1	8
2	4
3	3
4	2
6	1 1/2
8	1

TRACTOR SPEED CONVERSIONS

Miles per Hour	Feet per Minute	Time required in seconds to travel 100 feet	200 feet	300 feet
1	88	68	137	205
1.5	132	45	91	136
2	176	34	68	102
2.5	220	27	54	81
3	264	23	46	68
4	352	17	34	51
5	440	13.6	27	41
6	528	11.3	23	34
7	618	9.7	20	29
8	704	8.5	17	27

ACRES SPRAYED PER TANKFUL

Gallons per Acre	Tank Capacity 30	50	55	60	75	100	110	150	200	500
5	6.0	10.0	11.0	12.0	15.0	20.0	22.0	30.0	40.0	100.0
6	5.0	8.3	9.2	10.0	12.5	16.7	18.3	25.0	33.3	83.3
7	4.3	7.1	7.9	8.6	10.7	14.3	15.7	21.4	28.6	71.4
8	3.8	6.3	6.9	7.5	9.4	12.5	13.7	18.8	25.0	62.5
9	3.3	5.6	6.1	6.7	8.3	11.1	12.2	16.7	22.2	55.6
10	3.0	5.0	5.5	6.0	7.5	10.0	11.0	15.0	20.0	50.0
15	2.0	3.3	3.7	4.0	5.0	6.7	7.3	10.0	13.3	33.3
20	1.5	2.5	2.8	3.0	3.8	5.0	5.5	7.5	10.0	25.0

CONVERTING WIDTH OF AREA COVERED TO ACRES TRAVELED PER MILE

Width of Strip (feet)	Acres per Mile
6	.72
10	1.21
12	1.45
16	1.93
18	2.18
20	2.42
25	3.02
30	3.63
50	6.04
75	9.06
100	12.1
150	18.14
200	24.2
300	36.3

TRACTOR SPEED AND SPRAY RATES

$$\text{Tractor Speed} = \frac{\text{gallons per minute} \times 495}{\text{gallons per acre} \times \text{width of spray}}$$

$$\text{Gallons Per Acre} = \frac{\text{gallons per minute} \times 495}{\text{miles per hour} \times \text{width of spray}}$$

$$\text{Tractor Speed} = \frac{0.682 \times \text{distance}}{\text{seconds}}$$

$$\text{Gallons Per Minute} = \frac{\text{gallons per acre} \times \text{miles per hour} \times \text{nozzle spraying in inches}}{5{,}940}$$

CALIBRATION OF NOZZLE FLOW RATES

Gallons per Minute	Seconds for 1 pint	Gallons per Minute	Seconds for 1 quart
.05	150	.175	86
.06	125	.20	75
.07	107	.225	67
.08	94	.25	60
.09	84	.30	50
.10	75	.325	46
.11	68	.35	43
.12	62	.40	38
.13	58	.425	35
.14	53	.45	33
.15	50	.50	30

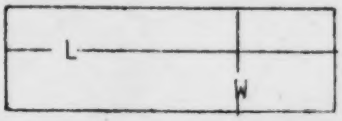
Compiled by Herbert Cole, Jr., Professor, Plant Pathology

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AREA MEASUREMENTS

Calibration of equipment depends on your ability to measure the area to be treated. If the area is a rectangle, circle, or triangle, simple formulas may be used.

Rectangles: The area of a rectangle is found by multiplying the length by the width. Area = length x width

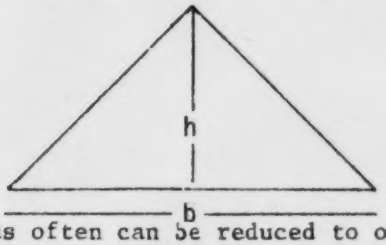


Circles: The area of a circle is the radius (one-half the diameter) squared and then multiplied by 3.14. Area = 3.14 x radius squared



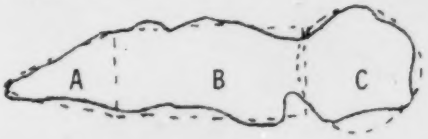
Triangles: The area of a triangle is one-half the base multiplied by the height.

$$\text{Area} = \frac{b \times h}{2}$$



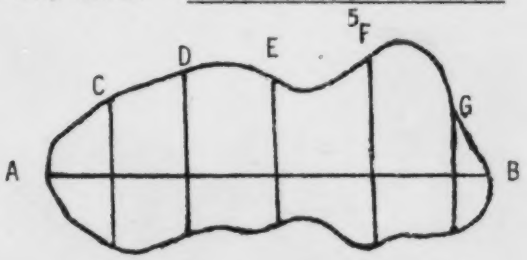
Irregularly shaped areas often can be reduced to one or more of these common shapes. Calculate the area of each and add them together to obtain the total area.

Example: Area A + B + C = Total Area



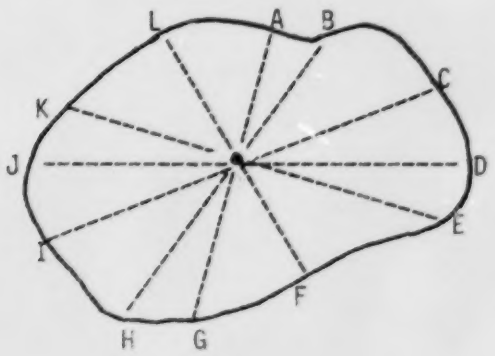
Another way is to establish a line down the middle of the property for the length, and then measure from side to side at several points along this line. Areas with very irregular shape require more side to side measurements. The average of the side measurements can be used as the width. The area is then calculated as a rectangle. (Area = length x width)

Example: Length = line AB; Width = $\frac{\text{line C + D + E + F + G}}{5}$



A third method is to convert the area into a circle. From a center point, measure distance to the edge of the area in 10 to 20 increments. Average these measurements to find the average radius. Then calculate the area using the formula for a circle. (Area = 3.14 x radius squared)

Example: $(3.14) \times \frac{\text{line A} + \text{B} + \text{C} + \text{D} + \text{E} + \text{F} + \text{G} + \text{H} + \text{I} + \text{J} + \text{K} + \text{L}}{12} = \text{Area}$



Section 4: Application Equipment

4. APPLICATION EQUIPMENT

A. Mist Spraying

Mist spraying still plays an important role in adult mosquito control, and mist sprayers can be used effectively for daytime applications of insecticide since wind and temperature conditions are less critical than for ULV operations.

The mist sprayers are large machines which require two persons for operation. They disperse insecticide in a water solution, necessitating a large storage tank. The solution is pumped from the tank and, under 400 psi pressure, is injected into a large volume of high velocity air. This process, which utilizes appropriate nozzles, breaks the solution into very small droplets. The blower is moveable to allow for operator control of the air stream with its entrained insecticide. In residential areas it is directed at an approximate angle of 45 degrees above the horizontal in order to clear roof tops and give maximum range of coverage. In woody and/or weedy areas, the spray is directed in an up and down movement for better penetration of foliage.

The mist sprayer disperses about two gallons of solution per minute at a forward speed of three to five miles per hour. Applications are made as needed, normally about once a week. Both sides of all streets are sprayed.

B. Foggers

The thermal fog machine produces a cloud of fine droplets which lingers near the ground and drifts through the area inhabited by adult mosquitoes. Fogging is effective only as a contact application.

Thermal fogging should be done only from evening to early morning to coincide with greatest activity of mosquitoes. Weather conditions should be conducive for allowing fog to remain close to the ground. The wind should not be greater than 3 mph. Fogs should be applied on one side of the street with the area to be fogged on the downwind side. This will take full advantage of the wind to carry the fog effectively. There are a number of commercial fogging machines which have different operating characteristics. The best results are produced when individual instructions for the machine are followed, and when weather conditions are optimum. This usually means an output of 30-40 gallons per hour with the vehicle moving about 5 mph and an air temperature of at least 65 degrees F.

Fuel oil is normally used as the carrier in formulations for thermal fog machines.

C. ULV Spraying

ULV (Ultra Low Volume) spraying is a relatively new method of adult mosquito control. It provides greater safety, effectiveness and economy than the mist sprayer. Temperature and wind conditions are critical when using these machines because concentrated insecticides are being dispersed in very small amounts. The best times to use ULV equipment are early in the morning or in the late evening.

The ULV aerosol generator is a small, compact unit which requires only one person for operation. It disperses concentrated insecticide without dilution. The insecticide container is pressurized to 4.5 psi (for the Leco HD unit), causing the insecticide to flow through appropriate tubing and controls to the discharge point. There it is injected through a nozzle, into a swirling air stream. The insecticide is broken into very fine droplets, virtually invisible after they move into the atmosphere. The ULV machine does not provide for controlled direction of the spray; it drifts to its destination on normal air currents. The spray is normally directed to the rear at an angle of 45 degrees above horizontal.

The ULV aerosol generator disperses 2.1 fluid ounces (of Cythion) per minute at 5 mph vehicle speed or 4.3 fluid ounces per minute at 10 mph vehicle speed. The insecticide flow rate varies with temperature and must be adjusted by means of a flow meter. Charts giving the proper flow meter settings for ambient temperature, vehicle speed and type of insecticide are available. ULV applications are normally made twice a week but may, under extreme annoyance conditions, be made daily. Only one pass is made per street.

The flow meter, thermometer, pressure gauge, hour meter, and control (on-off) switch are mounted on a panel in the vehicle cab within easy reach of the operator. The operator must monitor these controls and adjust the flow meter as the temperature changes.

During operation, should the forward motion of the vehicle be stopped for any reason, shut the insecticide flow off immediately. Allowing the flow to continue when forward motion is stopped may result in foliage injury and possibly other damage. It is contrary to the labeling instructions as defined by the Federal Environmental Pesticide Control Act.

Because of the noise level reached with some ULV equipment, the use of sonic ear valves is recommended. Cotton wads may be used if ear valves are not available but are not as effective.

Ultra Low Volume

The use of ultra low volume (ULV) insecticides applied by ground equipment is rapidly gaining acceptance for adult mosquito control in the Northeast. Several important factors have influenced this conversion to ULV equipment. Control of adult mosquitoes using ULV insecticides is better than or at least equal to that obtained with the conventional mist blowers. Only one man is required for ULV applications, whereas two men are needed for mist spraying. Maneuverability of the small pickup mounted ULV unit will permit access to off-the-road areas previously inaccessible to the large sprayers. Initial cost of equipment is much less. Fill-up time, an important factor in rural areas, is eliminated.

Installation of Leco ULV

The ULV aerosol generator should be permanently affixed to the bed of a truck following the instructions accompanying the machine. The truck should be equipped with a "slow vehicle" warning sign. The can-rack unit holding the insecticide should be placed in such a manner that heat from the engine exhaust and motor block does not continually increase the insecticide temperature during mosquito control operations. The remote control panel in the cab of the truck must be placed so that the driver of the vehicle can easily see the controls and be within easy reach in order that adjustments may be made while the operation is in progress.

After permanently mounting the remote control panel, the electrical connections, insecticide line, and air hoses should be connected. Caution should be used when connecting the hoses to prevent leakage. The connections should be properly threaded and tightened only hand tight.

Operation of Unit

Be sure that the engine block is filled with oil. Fill the gasoline tank. Check to see that all lines are tight and that pressure is building within the tank. By adjusting the engine throttle, the pressure gauge on the instrument panel should read 4½ PSI. When filling the insecticide tank, be sure not to spill insecticide on the bed of the truck. When handling and pouring insecticide, be sure to wear protective clothing. The discharge head should be directed to the rear of the truck and angled 45 degrees above horizontal.

Calibration of Flowmeter

Before the unit is operational, it must be calibrated to deliver the desired flowrate per minute. The dosage recommendations will usually be given in terms of rate of flow. It must be understood that, even for the same rate of flow, each insecticide requires a different flowmeter setting due to the change in viscosity

caused by temperature changes. Therefore, it is necessary to calibrate your flowmeter for your particular insecticide at the temperature at which it will be dispersed.

During calibration, the ULV generator should be placed in an isolated area. The vehicle should be facing into the wind so that the spray is blown away from you and your equipment. Be sure it is not blowing towards people, houses, animals, etc. Start the generator engine and again check the pressure gauge for a reading of 4½ PSI. Open the flowmeter needle valve all the way by turning it in a counterclockwise direction. Turn the fog switch to "on". Allow the insecticide to flow through the system until all air bubbles disappear and then adjust the needle valve for the proper flow.

The proper flow rate for malathion ULV can be determined by the temperature correction curve furnished by Lowndes Engineering Company with the LECO ULV generator. Read the temperature from the temperature gauge on the instrument panel. Find this temperature on the correction curve. Then move straight up the page to the intersection of the temperature line with that of the plotted curve for the proper delivery rate. From that point or intersection, move across the page to the flowmeter so that the center of the floating ball is opposite the proper rate of flow.

To calibrate the flowmeter for the proper delivery rate, disconnect the insecticide line from the fogging head. With your flowmeter set to deliver a certain volume (ex. 4.3 oz/min.) catch the insecticide in a calibrated container for several minutes. Calculate the flow per minute. Upon completion, turn the fog switch to OFF and reconnect the insecticide line back to the fogging head.

In some instances, you may not be using the exact dosage rate plotted and will therefore have to make your own curve to fit your desired dosage rates. Refer to temperature correction curve for malathion. If, for example, you needed a flow rate of 4 oz. per min., read across the bottom of the graph labelled "flow" to 4. Then go directly up the line to where each of the temperature lines intersect the line above 4 and record each. You should get a flowmeter setting of 163 millimeters for 65 degrees F, and 85 mm for 100 degrees F. After having found the flowmeter reading for each fixed temperature between 65 and 100 degrees F, plot each point on a graph. Connect each point forming a gradual curve (not a straight line between points). After the free-hand curve has been drawn in, read the flowmeter setting for any temperature between 65-100 degrees F.

Temperature Flow Chart

Using the temperature correction curve for the insecticide and rate of flow that will be used, a temperature correction chart (see examples) should be made to include the proper flowmeter reading for each temperature reading between 60 degrees and 100 degrees F. This temperature correction chart should be attached to the instrument panel and be used to correct for temperature changes during operation.

Droplet Size Determination

The dosage rate is determined by the vehicle speed, the swath width and the rate of insecticide flow. Doubling your vehicle speed, other factors remaining constant, will decrease your dosage rate by one-half. The droplet size is determined by the flowrate, pressure, and the nozzle size.

The droplet size is extremely important in ground adulticiding because heavier droplets tend to fall to the ground and droplets too small tend to drift up and away from the target mosquito. More than one-half of the total spray mass must consist of droplets in the 6 to 18 micron range; 4/5 of the total spray mass must have droplets smaller than 24 microns. The mass median diameter of the droplets should not exceed 17 microns (50% of the spray volume is in not larger than 17 micron droplets and 50% is in smaller than 17 micron droplets).

The droplet size of your ULV non-thermal generator should be determined as frequently as necessary to insure proper droplet size. It must be determined before the machine is originally put into active use and following any mechanical changes or alterations. It should also be determined at regular intervals of approximately 50 operational hours. Label instructions for ULV chemicals specify the droplet size distribution required and these directions must be followed. Any equipment to be used for ULV application should be tested and demonstrated to be capable of producing the required droplet size distribution.

Droplet sizes are determined by depositing a sample of the aerosol onto a silicone coated glass slide and measuring the droplets under a high-power microscope. The slides may be prepared using silicone (General Electric SC-87 Dri-Film) or purchased ready for use.

A sample of the malathion aerosol is deposited on a slide by placing the slide onto the end of a 3 ft. stake and waving the slide through the aerosol cloud at a distance of 25 ft. from the point of discharge. The slides are waved perpendicular through the aerosol cloud and stored in a tightly sealed box for transfer to a location for counting.

Making Treatments

Your control district may be logically divided into several control areas. Each area should then be mapped with detail to include all roads and alley ways. The driver should familiarize himself with each area and plan his route of travel before leaving the control headquarters.

Do not drive with the wind blowing the insecticide into the cab of the truck or down wind of areas immediately treated. Never drive into unfamiliar driveways before checking for obstacles or hazards. Do not apply insecticides while going into a driveway, roadway, or in any other manner that will necessitate driving back through the insecticide.

Before leaving your mosquito control headquarters, you should make a routine check on the vehicle and safety equipment. Record pertinent information, such as treatment area, date, operator, flow rate, vehicle speed, fogging time, and meter reading before the operation begins.

After arriving at your area, you should note and record the time, wind direction, and approximate wind speed. Start your aerosol generator and check out all systems. Operate your emergency flashers. Turn the fog switch to on and adjust the flowmeter reading (refer to Flowmeter Temperature Chart). It is imperative that you maintain your assigned vehicle speed in order to deliver the proper dosage rate. When possible, drive at right angles to the wind.

D. Aerial Equipment

AERIAL APPLICATION MUST BE DONE BY A LICENSED AERIAL APPLICATOR. The key to successful aerial application of pesticides is UNIFORMITY of the initial spray deposit over the plant canopy. The chemical will be redistributed by dew, rain, or overhead irrigation to other parts of the plant including lower leaf surfaces, stems and fruit. The key to uniform aerial application is the DESIGN and ADJUSTMENT of the spray distribution system and the OPERATION of the aircraft.

The advantages are summarized below. Most important is the speed of coverage to combat widespread and fast developing epidemics when they strike major crops such as corn, cereal grain, potatoes, and vegetables. One aircraft can do more work in an hour than most ground rigs can do in a day. Aircraft can spray fields that are too wet for ground equipment, which is often the case when fungus pests are most active.

TEMPERATURE CORRECTION CHART

INSECTICIDE: Cythion (Malathion ULV)
RATE OF FLOW: 4.3 Fl. Oz./Min.
FLOWMETER TUBE: FP-1/4-23-G-6-3/4
FLOWMETER FLOAT: Stainless Steel

Temp. °F	Flowmeter Scale	Temp. °F	Flowmeter Scale
60	*	78	128
61	*	79	126
62	*	80	124
63	*	81	122
64	*	82	120
65	*	83	118
66	166	84	116
67	161	85	114
68	157	86	112
69	153	87	110½
70	149½	88	108½
71	146½	89	107
72	143	90	105
73	140½	91	103½
74	138	92	102
75	135	93	100
76	133	94	98½
77	130½	95	97

* Off the flowmeter scale

Advantages of Aerial Application

1. Faster
2. Better timing
3. Works on wet fields following rain or irrigation
4. Only feasible way to cope with pest epidemics
5. Eliminates sprayer wheel damage and soil compaction
6. Reduces mechanical spread of virus and bacterial disease
7. Spray deposits resist weathering better
8. Uses less water
9. No runoff
10. Lowers grower's capital investment
11. Reduces labor requirements

Disadvantages of Aerial Application

1. Some fields inaccessible or too uneven for successful flights
2. Inherent potential for environmental pollution and drift damage
3. Certain crops not suited to aerial application

Equipment and Operation

To consider an agricultural aircraft an "airborn-airblast sprayer" will put its function into better focus. Its efficiency depends on its adjustment and operation. The airstream from a fixed wing aircraft or helicopter moves outward and downward. The objective is to put the spray into this stream of air in such a manner that it comes out uniformly across the crop when spraying is completed. Swaths must overlap properly. The upper canopy of foliage is a primary target for insects and diseases of most crops. Penetration of vertical distribution will be adequate for most crops, except in unusual situations.

Swath Width

Most aircraft in calm air will disperse some spray to a width about twice that of the wingspan. The effective swath width is governed mainly by the weight and wingspan. Tight swaths give better lateral surfaces, perhaps even to the underside of leaves. For most field and vegetable crops, swaths at just beyond the wingspan of 26 to 40 feet for light aircraft and up to 45 feet for heavier craft are suggested. Optimum swath for helicopters is usually 5 to 10 feet beyond the normal boom length.

Flagging

Swaths should be marked at the end of the field with permanent flags or by a flagman. Swaths should be measured accurately with a chain or other device except

when rows can be accurately counted. Tests plots should be at least three swaths wide to avoid mixing of treatments.

Spray Volume

Experience has shown that the volume of aerial spray can be reduced significantly with no real loss in disease control. Whereas five to ten gallons per acre was considered minimal a few years ago for field and vegetable crops, volume of two and three are now used successfully. This necessitates well-designed and operated spray systems of either boom-nozzle or Micronair types. The water or other liquid vehicle in the spray serves no other function than to keep the mixture fluid until it is delivered to the target on the plant. Only sufficient water is needed to make the chemical sprayable. On vegetables and field crops, two to three gallons of spray volume per acre is considered optimum. Most orchard crops and vineyards can be handled with volumes up to five gal/A. Some very unusually tall or dense foliage crops or situations requiring greater penetration to the lower surfaces may benefit from slightly higher volumes, if aerial application is at all feasible. A slight increase in normal volume may be desirable under unusually low humidity conditions if some type of non-volatile carrier cannot be used. Spray volume is not nearly as important as the uniformity of the distribution of the chemical into the airstream of the aircraft.

Spray Adjuvants

The initial spread and coverage of the spray can be enhanced with a spreader-sticker on many hard-to-wet crops because they are smooth, waxy, or hairy. Properly chosen, such materials, sometimes known as surfactants, will greatly improve initial retention and will also aid redistribution without excessive runoff. Certain emulsifiable spray oils have also been used to advantage with aerial sprays. They improve spreading, tenacity, and redistribution and tend to reduce the evaporation of the spray in flight.

Ordinary household detergents or herbicide spray adjuvants are not recommended as agricultural spray adjuvants. They may cause too much foam, excessive runoff, and lower the tenacity of the spray deposit.

Type of Aircraft

Any of the commonly used makes and models of fixed wing or rotary agricultural aircraft will work if they have a good spray distribution system and are operated within their airmoving capacity. This is determined mostly by wingspan, weight, and speed. The aircraft is nothing more than the vehicle to haul the load. The choice will be governed by the type of operation and to a large extent the preference of the operator.

Spray Distribution Systems

Boom-nozzle or Micronair Rotary Atomiser sprayers are satisfactory for most fungicides and insecticides. Ultra-low-volume application such as "Mini-Spin" equipment is adaptable to certain insecticides but not fungicides.

Boom-Nozzle Systems

The majority of aircraft are equipped with boom-nozzle spray distribution systems. Either wing-enclosed or trailing-edge booms are satisfactory. Some home-made ones are a "plumbers nightmare."

Nozzle Spacing and Placement

On most aircraft, including helicopters, nozzles must be positioned asymmetrically (irregularly) on the boom, clustered or spread out as required at certain points to compensate for the distortion of the airstream by the propeller or from secondary eddies caused by the fuselage or wheels.

The larger the engine and propeller the greater the distortion will be. Regular or symmetrical spacing of nozzles produces a streaked, uneven pattern except on light, high-winged monoplanes. Many "customized" booms, especially after modifications according to the fancy of the operator, put out a very irregular spray pattern. Factory-installed booms with clustered nozzles as used on "Pawnees" and "Agcats" usually provide a uniform spray pattern. Unfortunately some new models of agricultural aircraft, although they are efficient aerial vehicles, are coming out of the factory with poorly designed spray booms(symmetrical and wingtip nozzles) that will require major modification and nozzle relocation. Most helicopters require minor clustering of certain nozzles to even out the pattern.

Wingtip Vortice

All aircraft produce a certain amount of vortice roll at the end of the wings or rotorblades. This can be used to advantage in aerial spraying if the spray released into the entrained air can be kept under control. If the boom is too long on a fixed wing aircraft, too much of the spray may be dispersed into upper air currents where it will be lost and subject to excessive drifting. To prevent this, nozzles shouldn't be used within two to three feet of the wingtip. The so called "high-capacity booms" with nozzles to the wingtip or beyond may be used for high-altitude, wide-swath, drifting-type application of insecticides to forest trees, but are not recommended for applying fungicides. Similarly, if the boom on a helicopter is too long, some spray will be released beyond the effective force of the rotor tip vortices. Helicopter booms should be only a few feet longer than the span of the rotors.

Nozzle Type

Hollow-cone nozzles such as Spraying Systems No. 4664 Diaphragm TeeJet fitted with a core (whirlplate) and orifice disc are recommended. "Whirljet" or flat-fan nozzles are not recommended because they are highly subject to wear and soon produce irregular droplet patterns. Discs and cores of cone nozzles are easily and economically replaced when worn.

Number and Size of Nozzles

For spray volumes of 2 to 4 gal/A, 20 to 30 well-placed nozzles are adequate. For volumes of 5 to 10 gal/A, 30 to 44 properly spaced nozzles are suggested. D-4 and D-6 with No. 45 cores are suggested for the lower volumes. D-8 to D-12 with No. 45 or No. 46 cores will be required for the high volumes. The final choice of the number and size of the nozzles depends upon the airspeed, pressure, and volume desired. Preliminary calculations can be made from manufacturer's nozzle capacity charts. Sizes can be mixed to change the output at strategic spots on the boom.

Controlling Droplet Size

The shear forces of the air passing over the face of the nozzles exert a far greater influence on droplet size than the pressure, airspeed or size of orifice used in normal application. The droplet size can be altered considerably by changing the angle of the nozzle into the airstream. The spray volume remains the same with no change in pressure or orifice size.

Nozzles pointing straight down or slightly backward will approximate the desired breakup of the spray for insecticide or fungicide application. Slightly smaller discs or higher pressures may be necessary on helicopters because of the slower flying speeds.

Nozzles pointing forward usually cause too much breakup and create droplets that are too fine and subject to drifting.

The nozzle pointed backward produces a very coarse spray, more subject to streaking and uneven coverage.

Changes in the nozzle angle can be made quickly on the entire boom if it is fitted with a flexible coupling and adjustable mounting. Streamlined or fixed booms that cannot be turned can be adjusted by turning the individual nozzles sideways or downward to the desired angle.

Pumps and Pressure

High-capacity pumps with one- or two-inch discharge are desirable on aerial sprayers for the relatively high volume and bypass agitation required for wettable powders. Operating pressures usually range between 25 to 50 psi for nozzle systems.

With soluble materials or emulsions, less agitation is needed.

Micronair Rotary Atomiser

This equipment has been used very successfully with pesticides on a large variety of crops. The individual units consist of propeller-driven rotating wire mesh cylinders. The spray mixture is pumped at low pressure to a central spindle and is discharged by centrifugal force. Droplet size is readily changed by adjusting the variable pitch blades on the units. The faster the rotation the finer the droplets. Droplet size remains relatively consistent regardless of the volume of spray being applied per acre. The delivery rate is altered quickly by adjusting the bypass or flow rate of the pump. The earlier standard model consisted of five rotating cages. The new compact model, AU 3000, with two cages, is lighter in weight. It can apply adequate gallonage for fungicides, yet is readily adapted to ultra-low volume insecticide use.

The Micronair Rotary Atomiser produces droplets of a more uniform size than a conventional nozzle. Spray volume of two to three gallons per acre is standard for Micronair and usually somewhat lower than boom-nozzle systems. Four atomisers are suggested for standard aircraft and six for the larger. Operating swath widths are the same as conventional boom systems on a given aircraft. Slightly higher flying altitude is suggested with Micronair equipment to permit full blending of the individual spray streams. Rotary atomizers have a tendency to put out ultrafine droplets. Operators are cautioned to avoid droplets that are so fine they result in waste and drift hazard. The initial cost of rotary atomizers is higher than a boom nozzle system, but this is offset by economies in operation and maintenance with greater flexibility.

Helicopters

Helicopters equipped with boom sprayers are used successfully for the application of pesticides on a wide variety of crops. They have the distinct advantage of being able to work small and obstructed fields. They do not require airstrips, and considerable ferrying time may be saved. The same gallonage rates recommended for fixed-wing, boom-nozzle sprayers are also recommended for helicopter application. The penetration of dense foliage is excellent with a helicopter at slow to moderate flying speeds. However, at normal operating speeds of 40 to 60 mph, the penetration of foliage has often been overemphasized. It is not necessary except in unusual cases because redistribution of the initial spray deposit corrects the irregularities. Helicopter operators are cautioned not to exceed optimum swath widths and flying speeds for the particular size and weight of helicopter being operated.

Climate and Operating Conditions

Wind

A wind of 2 to 6 mph is considered ideal, but aerial applications can be made in steady winds of up to 10 to 12 mph with little loss in effectiveness. Suitable adjustments should be made in droplet size under these conditions. Applications should be avoided in gusty winds or during the heat of the day when there are rising thermal air currents. Contrary to popular belief, sprays applied during dead calm and especially under temperature inversions fail to settle properly and may create serious drift problems. For convenience and efficiency, rows are usually planted the long way of the field and flown in the same direction. If there is a choice, a light crosswind during spraying is advantageous to equalize the distribution of the spray within the swath and between swaths and should be used whenever possible. In higher winds it may be better to fly up and downwind.

Rainfall and Dew

Sprays may be applied when plants are dry or wet with dew, rain or irrigation. Moisture on the plants at the time of spraying helps spread the initial spray deposit. Rewetting the foliage will redistribute the spray. Where permanent or solid set irrigation systems are installed, the water may be turned on for a few minutes to wet the foliage and then shut off before spraying each particular set.

Checking Spray Patterns

THE IMPORTANCE OF PRE-CHECKING EACH AIRCRAFT FOR DROPLET SIZE, UNIFORMITY OF PATTERN, SWATH WIDTH, AND SPRAY VOLUME CANNOT BE OVEREMPHASIZED. THIS MUST BE DONE BY ACTUAL TESTS.

Droplets Size and Distribution

A reasonably accurate job of checking the spray characteristics of an aircraft can be done on the airstrip. Some dyes will made a good pattern of pesticide particle size and concentration on semi-smooth finish or sign-stock paper. Highly absorbent composition paper or slick black plastic is not satisfactory. Tapes and strips blow about too much. Cards or small sheets of heavier stock can be stapled or tacked about two feet apart to wood strips and laid across the line of flight. A single pass at normal altitude should be made first. This will show the droplet size range, any gross irregularities in the pattern, and the width or lateral dispersion of the spray. An additional pass on either side at the projected swath width will show the degree and uniformity of the overlap. Corrective changes in nozzle location (uniformity), nozzle angle (droplet size), or swath-width (overlapping) can be made where indicated. Achieving a good spray pattern is largely a matter of trial and error, but pattern studies are necessary steps to accomplish

this end.

All airspray equipment should be carefully checked before the active spray season to avoid unnecessary and costly delays or faulty application with improperly serviced and adjusted equipment. Rechecks should be made during the season whenever changes are made in the spray distribution system.

Calibration

The spray volume must be known precisely in order to achieve the proper rate of chemical per acre. Once the swath width is established from the pattern tests and the sirspeed is known, further adjustments in volume can be achieved by changing the size of the nozzle discs and whirlplates or the pressure. Manufacturers nozzle specification charts should be consulted to make preliminary selection of nozzles. Calibration may be done by flying over a measured distance or by flying for a given length of time. The details of these methods are given in the following tables.

COMPUTATION OF ACREAGE AND MATERIALS

FORMULA: $\text{Acres covered} = \frac{\text{Length of swath in miles} \times \text{width of swath in feet}}{8.25}$

The number of acres in a swath of given width and length can be determined from the chart below.

Example: An aircraft with a 40-foot effective swath treats a strip one mile long. To find the number of acres, follow the 40-foot vertical column down until it intersects the 1-mile line. The answer to the nearest tenth is 4.8 acres. For swath widths other than those shown, interpolate or use combinations of the figures shown.

To determine the amount of pesticide required, multiply the acres by the desired rate of application.

ACREAGE CHART

Swath Length (Miles)	30' Swath	35' Swath	40' Swath	45' Swath	50' Swath	75' Swath	100' Swath	200' Swath	300' Swath	500' Swath
1/4	.9	1.1	1.2	1.4	1.5	2.3	3.0	6.0	9.1	15.2
1/2	1.8	2.1	2.4	2.7	3.0	4.5	6.1	12.1	18.2	30.3
3/4	2.7	3.2	3.6	4.1	4.6	6.8	9.1	18.2	27.3	45.4
1	3.6	4.2	4.8	5.5	6.1	9.1	12.1	24.2	36.4	60.6
2	7.2	8.4	9.8	10.9	12.1	18.2	24.2	48.5	72.7	121.2
3	10.8	12.6	14.5	16.4	18.2	27.3	36.4	72.7	109.1	181.8
4	14.4	16.8	19.4	21.8	24.2	36.4	48.5	97.0	145.4	242.4
5	18.0	21.0	24.2	27.3	30.3	45.5	60.6	121.1	181.8	303.0

AIRCRAFT CALIBRATION

FORMULA: $\text{Acres per minute} = \frac{2 \times \text{swath width} \times \text{miles per hour}}{1{,}000}$

The chart below shows the rate, in acres per minute, at which spray or dry material can be applied when swath width and speed of aircraft are known. For swath widths or aircraft speeds other than those shown, interpolate or use combinations of the figures shown. To find the rate of flow in gallons per minute or pounds per minute, multiply the acres per minute by the number of gallons or pounds per acre to be applied.

Example: A 100 mile-per-hour aircraft has a 40-foot effective swath. Follow the vertical 40-foot column down until the figure opposite 100 miles per hour is intersected. The aircraft would cover 8.0 acres per minute. If 1 gallon of spray is to be applied per acre, the aircraft should be calibrated to disperse liquid at the rate of 8 gallons per minute. If 10 pounds of dry material is to be applied per acre, the aircraft should be calibrated to disperse material at the rate of 10 x 8.0, or 80 pounds per minute.

ACRES-PER-MINUTE CHART

Speed M.P.H.	30' Swath	35' Swath	40' Swath	45' Swath	50' Swath	75' Swath	100' Swath	200' Swath	300' Swath	500' Swath
75	4.5	5.2	6.0	6.7	7.5	11.2	15.0	30.0	45.0	75.0
80	4.8	5.6	6.4	7.2	8.0	12.0	16.0	32.0	48.0	80.0
85	5.1	5.9	6.8	7.6	8.5	12.7	17.0	34.0	51.0	85.0
90	5.4	6.3	7.2	8.1	9.0	13.5	18.0	36.0	54.0	90.0
95	5.7	6.6	7.6	8.5	9.5	14.2	19.0	38.0	57.0	95.0
100	6.0	7.0	8.0	9.0	10.0	15.0	20.0	40.0	60.0	100.0
110	6.6	7.7	8.8	9.9	11.0	16.5	22.0	44.0	66.0	110.0
120	7.2	8.4	9.6	10.8	12.0	18.0	24.0	48.0	72.0	120.0
130	7.8	9.1	10.4	11.7	13.0	19.5	26.0	52.0	78.0	130.0
140	8.4	9.8	11.2	12.6	14.0	21.0	28.0	56.0	84.0	140.0
150	9.0	10.5	12.0	13.5	15.0	22.5	30.0	60.0	90.0	150.0